RELIABILITY ABSTRACTS and TECHNICAL REVIEWS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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Washington 25, D. C.

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PREFACE

With the expansion of our ballistic missile and space exploration programs, a great deal of concern has developed for the reliability of parts, assemblies, components, and systems. Many individuals and groups are currently working on various aspects of this general problem. These include research teams on specific development programs sponsored by the National Aeronautics and Space Administration, the Department of Defense and other government agencies, and scientists on pure and applied research in the universities and in industry. Known mathematical, statistical, and engineering methods are being applied; adaptations of known methods are being made, and entirely new techniques are being developed. These efforts are resulting in an ever-increasing volume of literature, both open and classified, published and privately circulated.

In order to help scientists in this field to stay abreast of the latest developments, the National Aeronautics and Space Administration in April, 1961 contracted with the Research Triangle Institute for the conducting of an abstracting and review service for technical literature on reliability. The work is performed by the Research Triangle Institute, Durham, North Carolina under the sponsorship and supervision of the Office of Reliability and Quality Assurance of NASA. Current papers on reliability and closely related subjects are sought from all available sources, including technical journals, trade magazines, and proceedings of conferences and meetings. Authors of papers and technical reports in the field have been invited to submit their material for inclusion in the service. Abstracts and reviews of the papers are prepared and submitted in monthly installments to NASA for distribution to a NASA mailing list. This volume contains Reliability Abstracts and Technical Reviews Serial Numbers 1-275, produced during the period between April, 1961 and May, 1962.

At the inception of work on this project it was proposed that, after some volume of material had accumulated, a subject category system for classifying the papers would be developed. Accordingly, the word "Category" was placed on each page, followed by a space for a number or group of numbers to be inserted later. It has since been decided to adopt for this classification purpose the American Society for Quality Control Literature Classification System, Methodology or Techniques Classification, as revised in June, 1962. A copy of the

code numbers of this system, together with the subject-matter categories for which they stand, appear on page three. Each of the 275 papers has been classified by the use of one or more of the codes of the Literature Classification System. The codes assigned to a given paper are intended to represent not only the principal subject matter of the paper, but also areas in which the contents may be expected to be useful. The codes assigned to the papers are given in the INDEX OF CODES BY SERIAL NUMBERS, which appears on pages seven, eight, and nine.

The chief value of the use of the Literature Classification System lies in the fact that it facilitates the search for material in given subject-matter categories. A listing has therefore been prepared of the serial numbers of the papers to which the various codes have been assigned. This listing appears as the INDEX OF SERIAL NUMBERS BY CODES, on pages four, five, and six. The user may find it worthwhile to transfer this list to a card file, using a separate card for each code number. The card file may then be kept up to date by appropriately entering on the cards the serial numbers of subsequent articles.

The abstracting and review service for technical literature on reliability is now in its second year of operation. Between 30 and 40 items of literature are processed monthly. Over 50 journals and trade magazines are routinely searched for relevant material, with the list being augmented as required. Programs and proceedings of meetings and conferences in which reliability and related topics are discussed are also searched. Authors of papers and/or technical reports on relevant topics are invited to submit their material. The cooperation of all who are interested in the technical aspects of reliability will be appreciated in this effort to obtain as complete coverage as possible of the current literature in this field.

000 GENERAL
- 010 QUALITY CONTROL DEFINITIONS/SYMBOLS

100 STATISTICAL PROCESS CONTROL
- 110 CONTROL CHARTS
  - 111 CONTROL CHARTS FOR VARIABLES
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- 120 PROCESS CONTROL REQUIREMENTS
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200 SAMPLING PRINCIPLES AND PLANS
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  - 214 SAMPLE SELECTION
- 220 SAMPLING PLANS
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  - 341 RECORDS AND REPORTS OF QUALITY
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  - 352 QUALITY STANDARDS
  - 353 QUALITY COST MEASUREMENT

400 MATHEMATICAL STATISTICS AND PROBABILITY THEORY
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- 510 TESTS OF SIGNIFICANCE AND CONFIDENCE INTERVALS
  - 511 SIGNIFICANCE TESTS
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- 520 DESIGN AND ANALYSIS OF EXPERIMENTS
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  - 523 SPECIAL METHODS FOR ANALYSIS OF DATA
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- 530 CORRELATION
  - 531 SIMPLE CORRELATION
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  - 533 RANK CORRELATION
  - 534 COVARIANCE ANALYSIS
- 540 CURVE FITTING
  - 541 LINEAR REGRESSION
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(AS REVISED JUNE, 1962)

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102	822;833	149	774;775;824
103	420;833;844	150	800
104	823	151	813;833;837;851
105	782;833	152	824;831
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120	831;862	167	813;830
121	831;838	168	524;833
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130	640;871	177	824;833;840
131	775;851	178	833;840;851
132	837	179	714;813;833;844; 851
133	810;816		
134	770;833;837;851	180	715;782;833
135	780;833;837;844; 851	181	710;782
		182	833;837;840

Serial Number	Codes	Serial Number	Codes
183	813;836	232	823;831;840;851
184	711;782;830;837	233	833;844
185	821;831	234	813;823;844;851
186	773;784;830;841; 850	235	802;820
		236	813
187	841;864	237	815;833
188	831;832	238	831;833;843
189	802	239	822;833
190	833;836	240	832
191	802;821;831;840	241	821;833;844;851
192	825;830	242	782;783;833
193	824;836;838	243	432;863;874
194	813	244	825;830
195	811	245	824;836;838
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197	835;862;863;871; 874	247	811
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198	821;860;870	249	835;862;863;871; 874
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200	823	250	821;860;870
201	640;813	251	815;816;831
202	222;823;851	252	815;816;831
203	523;851	253	810
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205	400;500	255	715;782;833
206	813;851	256	770;823;851
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209	813;830	259	820
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213	834;870	263	720;833;844
214	550;810	264	833;851;864
215	200;300;770;810	265	780;851
216	815;870	266	833;844
217	837;840	267	832
218	815;831	268	771;840;850;864
219	833;838;844	269	782;833;835
220	815;823;860	270	714;833
221	838	271	711;714;782;833; 835
222	770;780;830		
223	773;784;833	272	813
224	833;851	273	820;835;836;840
225	821;831	274	310;810
226	823	275	310;740;760;810; 836
227	820;831		
228	831;833;844		
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some discrete distributions associated with life testing

AUTHOR: J. G. Magistad, Sandia Corporation, Albuquerque, New Mexico

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 1-11, January, 1961

PURPOSE: To acquaint the reader with three discrete distributions which may be used to describe the number of successful operations or cycles prior to the failure of a device.

ABSTRACT: The distributions which are most commonly associated with life testing, viz. the exponential, gamma, Weibull, truncated normal, and log-normal, all consider time as a continuous variable. There are, however, many occasions on which it is more appropriate or convenient to consider life in terms of discrete units. Such occasions arise when it is impossible or inconvenient to continually monitor a device until failure, and life is measured in terms of the number of successful operations or cycles prior to failure.

This paper considers three distributions which may be used to describe the number of cycles prior to failure. They are: the geometric distribution, the negative binomial (Pascal) distribution, and another cycle-dependent geometric distribution referred to as a generalized type. The generalized type is so chosen as to be related to the Weibull distribution. Arguments to justify the use of these distributions are discussed. It is shown by a limiting process that the above distributions are related to the exponential, gamma, and Weibull distributions respectively. An example is used to show that when the mean time to failure is greater than 100 cycles, the exponential distribution is a reasonable approximation to the geometric distribution. It is reasoned that, since the geometric distribution is a specialized form of the negative binomial and the cycle-dependent distribution, a mean time to failure of 100 cycles is a minimum condition for their limiting distributions to give reasonable approximations to the discrete probabilities.

Various selected properties of the geometric and negative binomial distributions are shown.

REVIEW: This paper is a useful contribution to the theory of mathematical models in life testing. While the distributions considered are not new, their potential usefulness in life testing, and their relationships with certain common life distributions do not seem to have been pointed up elsewhere. The relationships between the discrete distributions and their continuous counterparts are derived mathematically. The results presented could be of interest to anyone setting up a model for the life testing of a device in which life is measured as

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the number of successful operations before failure, particularly if the mean time to failure is considerably less than 100 cycles.

The general conclusion that for a mean time to failure greater than 100 cycles the limiting distributions give reasonable approximations to the discrete probabilities has not been rigorously established in this paper. It is effected only by reasoning from a special case to the general case.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A sequential test to measure and improve reliability

AUTHOR: Stuart A. Bessler, General Telephone and Electronics Laboratories, Inc., Menlo Park, California

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 111-117, January, 1961

PURPOSE: To formulate and solve a simple problem in system reliability using the sequential design of experiments technique.

ABSTRACT: The system considered consists of two components which operate in series and fail independently. It is desired to have the system function with given reliability, expressed in terms of the reliabilities of the separate components. Three states of nature are assumed, in only one of which the system has the desired reliability. In the other two, one component has the desired reliability, while the other falls short of this value to an extent expressed as a fraction of the desired percentage of non-defectives in the population. The problem considered is that of identifying the true state of nature by means of the sequential design of experiments technique, given that the experimenter may test either component separately, or may test the assembled system.

The general theory of the sequential design of experiments is summarized. The sequential decision procedure for the given system is described. An alternative procedure is also described and its efficiency is determined. The details for the two procedures are presented.

REVIEW: This paper has value as a summary and illustration of the sequential design of experiments technique. However, from the standpoint of direct practical utility in reliability studies it is rather limited, since the system considered is one of the simplest possible, consisting of two components in series. The author points out that the paper provides a means of resolving the problem of determining whether to test components or complete assemblies. This feature is, of course, subject to the above limitation. The extension of these ideas to more complex systems would be desirable.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability from the program manager's standpoint

AUTHOR: Clifford M. Ryerson, Radio Corporation of America, Camden 2, New Jersey

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 169-181, January, 1961

PURPOSE: To relate reliability control considerations to management objectives in the electronics industry.

ABSTRACT: The program manager's prime objectives are summarized as being to get the job done and to deal with troubles. In the past the approach commonly taken has been one of simply applying good practice techniques in all areas of work, referred to by the author as the "good practices" approach. The reliability requirements of modern electronic equipment demand a more formal controlled approach.

In the "good practices" approach the manager generally delegates responsibility and authority to assistants, thereby losing direct contact and control of the project. This approach has succeeded in the past because of such factors as the simplicity of systems, the availability of suitable parts, people experienced on similar projects, and the absence of specific reliability requirements. Present conditions require central direction and technical control of projects, a "reliability control" approach.

The program manager's responsibility for getting the job done is divided into four objectives including scheduling, lowest cost considerations, customer satisfaction, and agreement with company policies and objectives. The role of reliability control in each of these objectives is examined. Various aspects of the problem of preventing and correcting program difficulties are set forth and discussed.

REVIEW: This paper is written for program managers at all levels in the production of electronic equipment. It is an effort to wean them away from the old easy-going practices that no longer work with complex equipment. It contains no engineering or statistics, but emphasizes the problems and responsibilities of managers. It should be noted that in discussing project stages the author has omitted any reference to the design review phase.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A unique allocation of required component reliability

AUTHOR: Arthur M. Breipohl, Sandia Corporation, Albuquerque, New Mexico

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 189-202, January, 1961

PURPOSE: To describe a method for uniquely establishing component reliability requirements from system reliability specifications.

ABSTRACT: When design specifications include a reliability requirement, it is necessary to decide how reliable each component must be in order to meet the required system reliability. In the absence of some constraints, there is no unique solution to this problem, since a system having n possible failure events admits of n-1 degrees of freedom in choosing the allowable failure probabilities of the n failure events.

Reliability may be regarded as a function of many factors. Of these, the author chooses to use cost, and considers the problem of allocating component reliability in such a way as to achieve the minimum system cost. The predicted failure events are discussed in the two categories (a) catastrophic failures and (b) out-of-tolerance failures. In (a) a cost versus failure model is assumed and a unique allocation of component failure probability that results in a minimum cost is determined. In (b) a cost versus standard deviation model is assumed and a unique allocation of the standard deviation of the component performance variables that results in a minimum cost is determined.

The models introduced are arbitrary, meeting suitable boundary conditions at zero and infinite reliability. The influences of component reliability on system reliability and of component cost on system cost are developed. Various approximations are used in order to solve the problems. An example is given for catastrophic and for out-of-tolerance failures. The necessary mathematics is derived in two appendices. A brief comment is made about the allocation of the total allowed unreliability between out-of-tolerance and catastrophic failure rates.

REVIEW: While an attempt is made to be completely analytic, the assumptions are quite arbitrary and the results are quite dependent on the models chosen. This must be borne in mind in considering the applicability of the methods and results to a practical system, in order to avoid misleading conclusions. In addition to deciding on the appropriateness of a particular function to relate cost and failure probability, the user will require data from which to determine the constants of the function for each failure event.

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RELIABILITY ABSTRACTS
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No attempt is made to deal with permissible deviations from the optimum solution; i.e. how broad are the partial minima? This may be rather important in some cases. Only component and not development costs are considered. For systems of any great complexity, solution by the proposed methods is likely to become quite involved. It would appear that the paper is more useful as an illustration of cost minimization than for the specific results obtained.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Accelerated tests and predicted capacitor life

AUTHORS: D. Mannheim and R. Russell, Research and Engineering Department, Sprague Electric Company, North Adams, Massachusetts

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 253-261, January, 1961

PURPOSE: To discuss the factors affecting the reliability of oil-impregnated capacitors, and the prediction of capacitor life.

ABSTRACT: Knowledge of the life characteristics of capacitors is essential to the application engineer in electronics. Failure rate patterns and the effects of voltage and temperature on capacitor life are important factors in making reliability predictions.

Failure rate patterns for capacitors have a shape determined by the presence of both chance failures and wear-out failures. The typical curve has a first mode at zero time, followed by a negative concave slope to a minimum, after which the curve rises again to a second mode, and finally drops asymptotically to the abscissa. Because of difficulty in using this curve in making predictions, it is usually approximated by a straight line (constant failure rate).

A rule which has been in common use for calculating the effect of voltage on capacitor life is the fifth power law. This law states that the D.C. life of a capacitor varies inversely as the fifth power of the applied voltage. There is, however, evidence to indicate that the power may vary between 2 and 10 depending on the construction of the capacitor. Accelerated life tests may be used to determine the power law for a particular capacitor type. Another commonly-used rule is that capacitor life decreases by a factor of two for every 10°C increase in ambient temperature, and conversely. Results obtained in the present study cast some doubt on the validity of this rule. The voltage and temperature effect calculations may be combined into a single relationship. Examples showing the application of this relationship are given.

REVIEW: There seems to be an inconsistency in the models described in this paper. In the first part care is taken to show the marked variations in failure rate over time. Then data are introduced which show that the rate is constant.

No comment is made on the effect of temperature on the voltage law. The chief merit of the paper seems to be that it destroys faith in two rules of thumb.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Designing reliability into the B-58 bombing-navigation system

AUTHORS: Mordecai D. Katz, Herbert Jaffe, and Stanley A. Rosenthal, Air Armament Division, Sperry Gyroscope Company, Division of Sperry Rand Corporation, Great Neck, New York

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 273-282, January, 1961

PURPOSE: To describe the operation of the B-58 bombing-navigation system (AN/ASQ-42V) and to illustrate the way in which mathematical models were used to optimize the system reliability.

ABSTRACT: The AN/ASQ-42V bombing-navigation system generates navigation information from sensors and computes course corrections, bomb and missile release information, as well as other data. These functions are briefly described and illustrated.

High reliability in this system was achieved by:

1. Paralleling complete circuits with identical spare units.
2. Paralleling selected units with redundant replacements.
3. Providing spare units to replace any of several units performing similar functions.
4. Providing less-accurate alternate methods of performing complex computations.
5. Use of self-sensing fail-safe design techniques.

Some simple algebra shows the basic calculations involved in reliability-weight-volume trade-offs. The operation of a malfunction subsystem is briefly described. The concepts of circular probable error and system worth are discussed. Reference is made to mathematical models which were developed and programmed for computers, for use in determining the effects of changing the system.

REVIEW: This paper is a general qualitative review of the methods used in designing for reliability in a complex electro-mechanical system. It is more "interesting" than "informative." Undoubtedly the authors could supply much more technical information to those who "need to know."

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The dollar value of improved reliability

AUTHORS: E. L. Welker and C. E. Bradley, ARINC Research Corporation, Washington, D. C.

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 323-339, January, 1961

PURPOSE: To focus attention on the savings to be realized from scheduling of preventive maintenance and from improvements in reliability.

ABSTRACT: This paper develops a nomograph permitting computation of the maximum cost increment which can be paid for improved reliability on the basis of (1) a criterion for determining a preventive maintenance schedule and (2) the associated curves relating average cost per mean life to the fundamental cost parameter. The nomograph is distribution-free. The basic cost curves, however, depend on the preventive maintenance policy and the underlying density. Some examples suggest very strongly that the cost increment is sensitive to the coefficient of variation but that it is relatively insensitive to the exact form of the density function.

REVIEW: The consideration here is the additional amount which one could pay for an improved part without sacrificing the savings accruing from a revised preventive maintenance policy. The calculations are straightforward, though a little involved. The method should be useful in situations in which the assumptions are satisfied.

The analysis is given for only two time-to-failure density types, viz. the normal and the gamma, although a hope of including other densities in later studies is expressed. The authors point out that the exponential is of trivial significance in the present problem, since the cost increment is directly proportional to the increase in mean life. They also indicate that there is some question as to the critical nature of the exact form of the density in many instances of prediction, preventive maintenance scheduling, and average cost estimation.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Self-correction in large-scale digital computers

AUTHORS: Fred Gerrand and Harold S. Rasmussen, International Business Machines Corporation, Federal Systems Division, Kingston, New York

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 351-360, January, 1961

PURPOSE: To discuss techniques of error detection and error correction in large-scale digital computers, with particular reference to a method employing built-in error detection equipment and programmed error correction.

ABSTRACT: The philosophies and design techniques of error detection and error correction as applied to large-scale digital computers are discussed. The logical design of the error detection system for the data transfer, arithmetic, control, encoder, and decoder units are described. An automatic recovery program called "Fix", utilizing the speed and decision-making capabilities of the computer, provides for automatic recovery from errors in a matter of milliseconds, while requiring less than 3 percent of the basic core memory and drum storage space for error correction.

The system is designed in such a way that when a fault is detected, the operational program is immediately interrupted and control is shifted to an automatic recovery routine. After completion of the recovery process, control is returned to the main program at the point of interruption. A better than three-fold improvement in the mean-time-before-failure of the system is obtained using this method of complete error detection by equipment and automatic error correction by program.

The error-free time of a system incorporating this self-checking capability substantially exceeds that of a system which embodies only conservative equipment design and the use of the most reliable components.

REVIEW: The different methods of automatic error correction are mentioned briefly; the economic justification and design objectives are sufficiently described, but considerably more detail is given for the error detection system than for the error correction process.

The overall approach to the error detection and error correction in large-scale digital computers is quite sound, but little justification is given for the magnitude of the mean-time-before-failure improvement.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A transistor reliability philosophy applied to the BMEWS

AUTHORS: Edward M. Yanis and Albert L. Goldsmith, Radio Corporation of America, Missile and Surface Radar Division, Moorestown, New Jersey

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 417-428, January, 1961

PURPOSE: To describe the approach taken by RCA, M & SRD toward assuring transistor reliability and the results of this philosophy as applied to the BMEWS.

ABSTRACT: RCA, the prime contractor on the Ballistic Missile Early Warning System, decided to use transistors for the active components. They realized the necessity of adequate reliability information to permit the circuit designers to make the optimum choices. Not only was the reliability information necessary initially, but a continuous program for monitoring the reliability was set up. Ninety-seven percent of the transistors were of 23 preferred types. This allowed a lot of testing to be done on them economically. The design-life (worst case) was 10,000 hours. One transistor type was found to be overrated and a second was found to be too unreliable for further consideration.

Rules-of-thumb for parameter degradation were established for the reliable transistors. The results of field data and life tests were combined in a nomograph for prediction of failure rate when the ambient temperature and power dissipation are known.

The authors claim that "the results of this program form a dramatic history of effort and achievement."

REVIEW: Efforts of this sort are essential to the progress of reliability. The paper is expository; explicit information is missing except for the "rules-of-thumb" and the failure rate-operating power nomograph. Transistors are identified as "DEP-type" only.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A comparison of methods of drift reliability determination

AUTHORS: Don M. Larson and Bruce J. Grinnell, International Business Machines Corporation, Federal Systems Division, Owego, New York

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 448-458, January, 1961

PURPOSE: To compare three methods of determining the drift reliability of electronic circuits.

ABSTRACT: A comparison is made of three methods of determining the drift reliability of electronic circuits. The circuit life testing method is quantitative and detailed but limited because of time and cost. The circuit analysis testing method produces qualitative results with a comparatively small expenditure but is limited in its inability to vary all component parameters as the complexity of the circuit increases. Prediction techniques are quantitative but depend upon workable circuit equations. The program indicates that quantitative prediction techniques augmented by qualitative circuit analysis testing could result in a practical method of determining drift reliability; however, application of these methods is limited by the lack of component part data. (Author)

REVIEW: This is an interesting comparison of the application of three commonly-used approaches to the problem of assessing system reliability. It would seem that more exploratory work should be done to see if better agreement among the methods can be obtained. Quite a few data are presented in the paper, so that the reader can make some evaluations himself. It is worth noting that the lack of data on drift characteristics of component parts stands as a serious obstacle to the application of what otherwise seems to be the best of the three methods.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Circuit-analysis techniques utilizing digital computers

AUTHORS: H. S. Scheffler and L. H. Stember, Jr., Battelle Memorial Institute, Columbus, Ohio, and J. J. Duffy, Autonetics Division of North American Aviation, Downey, California

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 361-374, January, 1961

PURPOSE: To describe a generalized technique of circuit analysis that makes use of the capabilities of high speed digital computers.

ABSTRACT: The method of circuit analysis used attempts to simulate the circuit mathematically on a digital computer and to show how the circuit will behave as its parts deteriorate during life. This is accomplished by programming the circuit equations into the computer and methodically varying the values of the part-parameters. The method has been programmed in a general manner so that it may be applied to many circuits with only minor modifications in the program; it does not require extensive data from large-sample life tests on the electronic parts used in the circuit.

The analysis of the circuit entails the following steps:

1) Draw an accurate equivalent circuit.

2) Write the circuit equations and circuit requirements in terms of the part-parameters.

3) Incorporate the equations, the circuit requirements, and the desired part-parameter variation ranges into the general computer program.

4) Debug and run the computer program.

5) Plot and analyze the computer output.

The circuit equations are expressed in matrix form and a general matrix-solution subroutine is used to solve them. The analysis is suited primarily to a.c. and d.c. steady-state conditions. It is not suitable for evaluating circuit behavior during a switching period.

REVIEW: This paper should be of particular interest to the engineer or circuit designer who is interested in a general method for analyzing the limits placed on the circuit components and parameters.

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Although it is primarily designed for utilizing parameter-drift life-test data, the authors state that the parameter-variation logic may be replaced with a statistically-based method of combining the data and the circuit equations to provide predictions of the distributions of the circuit functional parameters.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability growth prediction during the initial design analysis

AUTHOR: D. R. Earles, The Martin Company, Denver, Colorado

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 380-393, January, 1961

PURPOSE: To analyze, and find out how to predict, the reliability of equipment in its design and development period.

ABSTRACT: This paper presents a reliability growth prediction technique, based on the most recent available data, that is applicable to the accelerated design and development of present day weapon systems.

A survey of the failure rates from several projects under different installation environments reveals that there is a wide variance for the same component parts. This variance exists under the same environment and under different environments. It is proposed that the range in failure rates is due to the manner in which a component is applied in a circuit, the environment in which it is operated, and the maintenance philosophy employed. This variance in the observed failure rates of component parts is what causes such a difference in the failure rates used by various companies. To arrive at a set of failure rates for use in reliability predication, allocation, and analysis, data were analyzed from as many projects and installation environments as possible to derive the average.

A plot of the data indicates that there is a correspondence between the failure rate of a component part and its installation environment. Subsequent analysis showed that a generic failure rate could be obtained for each component part. The generic failure rate is the inherent number of failures per unit of time that will occur under laboratory conditions. Each component part can be described by its mean and extremes. It is synthesized that this distribution can be construed as a measure of the average design and its extremes -- design growth potential. The techniques developed were tested against systems for which growth records were maintained, and a relatively high degree of correlation was obtained. (Author)

REVIEW: This is an excellent paper. There is a comprehensive table of reliability of components (giving the mean and extremes) and a figure showing the derating necessary for different kinds of installations. The data and discussion should prove very helpful, especially to those in smaller companies who probably have had difficulty in finding this kind of information. More efforts of this kind are necessary, together with the publishing of the results.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effects of on-off cycling on equipment reliability

AUTHOR: R. J. Boteilho, ARINC Research Corporation, Washington, D. C.

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 302-312, January, 1961

PURPOSE: To present the findings of an investigation of the effect of power cycling on the reliability of electronic equipment.

ABSTRACT: Four hypotheses were tested in an investigation of electronic equipment aboard the aircraft carrier USS Forrestal. The hypotheses were: 1. The reliability will be greater when the equipment is operated continuously rather than when cycled on-off as required. 2. The formula

$$b_t = b_o + b_c(N) \text{ is reasonably accurate,}$$

where b_t = total malfunctions/hr of operation

b_o = malfunctions/hr (in continuous operation)

N = number of on-off cycles/hr.

3. A large portion of the malfunctions occur in the first 10 minutes of operation. 4. Defects in tubes removed from cycled equipments will be predominantly mechanical, whereas the ones from non-cycled equipments will be due largely to wear-out.

It was impossible to have any equipments operated continuously since there were primary power failures and equipment repairs. Thus the two categories were, in effect, minimum vs. normal on-off cycling.

The first 3 hypotheses were substantiated in general; the fourth was not. No real differences were found in the defects of the two groups of tests. The coefficient, b_c, was about 8 b_o, which leads to some economic considerations. Even though the mean-time-between-failures was greater for continuous operation, the maintenance is more because the time of operation is much longer.

These conclusions are expected to apply to similar equipment using electron tubes. Radically different items, such as transistorized computers, should be tested to find their behavior.

REFERENCE: ARINC Research Corporation Report "Effects of Cycling on Reliability of Electronic Tubes and Equipments", June 30, 1960, Publication No. 101-26-160.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: This seems to be a good piece of work - for which the need was very clear. Certainly other studies of a similar nature - perhaps on Air Force, Army and industrial equipment - should be made. (For example, should test equipment at a repair station be left on at night?) The report cited above gives more complete information.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the basic concepts of reliability prediction

AUTHOR: George T. Bird, Engineering Consultant, ARINC Research Corporation

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 51-55, January, 1961

PURPOSE: To acquaint the newcomer with the need for reliability prediction all the way through a project.

ABSTRACT: Reliability cannot be added to a system; it must be built in. There are six important concepts that must continually be kept in mind.

1. Reliability prediction is a design process.
2. Reliability is a measurable design characteristic of a product or system.
3. Reliability is a predictable product design parameter.
4. The reliability of a product or system is a function of the parts, stresses and tolerances which are intrinsic in its basic design.
5. The reliability of a system can be predicted through a prediction of its performance characteristics.
6. The reliability of a design can be predicted from a knowledge of its stress/strength characteristics.

REFERENCES: There are 19 references listed; the four which give numbers for reliability prediction are repeated here.
1. Reliability Stress Analysis of Electronic Equipment, TR-1100, Radio Corporation of America, November, 1956.
2. ARINC Report No. 2, Air Force Reliability Assurance Program, ARINC Research Corporation, April 1, 1959.
3. J. H. Hershey, Bell Telephone Labs., Proceedings of 3rd Signal Maintenance Symposium, Ft. Monmouth, New Jersey, 1959.
4. Rome Air Development Center TR-58-111, ASTIA Document No. AD 148868, Reliability Engineering Handbook.

REVIEW: This is an introductory paper for those not yet acquainted with the area of reliability prediction.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure reporting and corrective action programs

AUTHOR: J. R. Holmes, International Business Machines Corporation, Federal Systems Division, Owego, New York

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 149-162, January, 1961

PURPOSE: To describe an effective program, already in use, for failure reporting and corrective action during development, production and field use.

ABSTRACT: The inclusion of the development phase in this program is important since changes here can be made more easily and less expensively. Changes put into effect during production cost much more and tend to require crash programs (with attendant problems).

The system evaluation can be split into five parts:

1. Applied research - this program is not applicable here.

2. Paper design - the program starts here. The disadvantage of being very fluid is offset by the ease with which changes can be made and the length of time before the delivery date. This is the optimum time for corrective action. Failure rates are estimated from published or proprietary information. (Caution must be exercised since published data vary widely.) A mathematical model of the system (and its components) is derived. Parts of the system which need attention or redesign are discovered and fixed immediately.

3. Engineering testing - test data become available here. A big problem is to get enough results to have engineering significance.

4. Production - this phase is characterized by the seriousness of any changes and the need for rapid action.

5. Customer use - the focus of all previous efforts. There are usually more failure data here, but corrective action can be most expensive.

The organization of the program is important; high enough management levels must be open to the reliability group and the forms and reports must contribute to successful performance. The forms in use are listed (some samples are shown) and discussed. One feature of many of the forms is the space for recommended corrective action and, in one form, the space for the engineering department's official reply.

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For the program to be successful, the reliability group must be staffed with excellent people in whom the rest of the organization has confidence.

REVIEW: This paper shows how one division of IBM is handling its reliability program. Some of the merits of the program are that it starts at the beginning and never quits, that it has adequate access to top management, and that it is designed (at least in part) to be used by fallible people. Engineers would do well to read this paper to get an insight into a larger picture. Reliability programs in general should place more emphasis on their use by ordinary people, who have sins of omission as well as of commission.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Application of AGREE Group 3 recommendations to military electronic equipment - case histories and conclusions

AUTHOR: Griffith W. Lindsay, Staff Engineer, Communications & Reconnaissance Division, AMC, ASC, Wright-Patterson Air Force Base, Ohio

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 317-322, January, 1961

PURPOSE: To show that AGREE Group 3 recommendations are not only practical but very worthwhile.

ABSTRACT: The paper is limited to the application of AGREE Group 3 recommendations to production procurements of Government Furnished Aeronautical Equipment for Communication, Navigation and Reconnaissance. The Group 3 recommendations are briefly reviewed. If the reliability requirement is to be enforceable it must include a statement of requirements and of the tests to prove compliance. These concepts are discussed. Four representative case histories show the application of AGREE Group 3 testing to production contracts. In all cases this testing pinpointed weak areas which were then corrected. In one case, field reports seemed to indicate random failures, but these tests found the causes of the failures. Poor management was shown to be part of the difficulty in two cases. Two contractors were enthusiastic about the Group 3 testing after they had done it. Several recommendations are listed at the end, and exhibits of reliability contracts are given in the appendix.

REVIEW: This paper is an enthusiastic endorsement of AGREE Group 3 recommendations. It should be of interest to design and production engineers (besides those directly involved), whose products must meet these requirements. A knowledge of the AGREE report (1957) would be helpful before reading the paper. The author obviously favors rather stringent environmental testing. This emphasis on the need for proper (not just financially successful) management is good.

REFERENCE: Reliability of Military Electronic Equipment, Advisory Group on Reliability of Electronic Equipment, Office of the Assistant Secretary of Defense (Research and Engineering), 4 June 1957, pp. 109-208.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The robustness of life testing procedures derived from the exponential distribution

AUTHORS: M. Zelen and Mary C. Dannemiller, National Bureau of Standards

SOURCE: Technometrics, vol. 3, pp. 29-49, February, 1961

PURPOSE: To study the behavior of four life testing procedures based on the exponential failure law when the true failure law is a Weibull distribution with the same mean life.

ABSTRACT: Almost all the statistical procedures in current use for evaluating the reliability of components or equipment rest on the assumption that the failure times follow the exponential distribution. However, in practical situations, one rarely has enough data to determine whether failure times are actually exponential. This paper studies the behavior of several statistical life testing procedures, based on the exponential failure law, if the true failure law is the Weibull distribution. It is found that these statistical techniques, which are widely used, are very sensitive to departures from initial assumptions. Applying these techniques to life test data when the exponential failure law is not satisfied may result in substantially increasing the probability of accepting components or equipments having poor mean-time-to-failure.

This paper also develops convenient analytic techniques for approximating (i) the distribution of sums of independent random variables, and (ii) the characteristics of sequential procedures, for non-negative random variables. These techniques are based on a general life distribution which consists of an expansion of generalized Laguerre polynomials. Application of these methods to the Weibull distribution yields excellent results. (Authors)

The life testing plans studied are (1) fixed sample size, (2) fixed sample size with censoring, (3) truncated non-replacement, and (4) sequential. None of the four procedures is robust with respect to Weibull alternatives. That is, the four plans are quite sensitive to a departure from the assumption of an underlying exponential distribution, although this is less markedly the case for plans (1) and (4) than for plans (2) and (3). The use of these procedures without a careful verification of the assumption that failure times follow the exponential distribution may result in a high probability of accepting poor quality equipment.

Appendix I is a discussion of analytical methods for studying the robustness of life testing procedures based on the exponential distribution. It includes the development of the properties of a general life distribution which can be used both when some of the lower order moments differ from those of the exponential and also

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

when specific alternative distributions are specified for the failure times. A discussion of two tests for the validity of the exponential assumption is given in Appendix II.

REVIEW: This paper calls attention to the dependence of certain statistical life testing procedures on the validity of the assumption of an underlying exponential failure law. It is valuable in reminding users of these techniques that unless the times-between-failure do in fact at least nearly follow the exponential distribution, seriously misleading results may be obtained, or the risks of incorrect decisions may deviate considerably from their nominal values. The results obtained for the four life test plans are of direct practical interest to anyone using these plans.

The developments in the two appendices will be of interest to the mathematical statistician concerned with tests for the validity of the exponential assumption, and/or the problem of studying the robustness of life testing procedures.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Military specifications affecting reliability

AUTHOR: H. L. Wuerffel, Defense Electronic Products, Radio Corporation of America, Camden 2, New Jersey

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 56-83, January, 1961

PURPOSE: To help provide an understanding of military specifications having to do with reliability, and to show that reliability can be specified.

ABSTRACT: The role of military specifications as a communication medium between the military and industry is discussed, and some reference is made to their history. The ground rules for good specifications are considered, and recently-written reliability specifications are compared with them.

Table 1 provides a listing of military standards, specification bulletins, exhibits, technical reports and notebooks containing parts specifications having explicit reliability requirements. Many of the listed documents have specification status.

Figure 2 is a block diagram, illustrating one way of classifying government documents containing specifications relating to reliability. Classification is made on the basis of the importance of the category; "weapons systems" is the most important one in the illustration, while subsidiary categories are equipment, wiring, parts, circuits and modules, and product assurance. Further breakdowns of subsidiary categories are given under "equipment," and "product assurance."

Table 2 is a listing of the specifications falling into the following categories:

Weapons Systems
Equipment
Product Assurance, Quality Control, Testing
Product Assurance, Reliability and Maintainability
Product Assurance, Environment
Parts
Circuits and Modules
Wiring
Guidance Documents - Reports and Handbooks.

Brief indications of the scope and objectives of each of the listed documents are given.

Table 3 lists the characteristics of ten of the most important equipment specifications as they bear on reliability. Of these, only two call for no demonstration of reliability. The first may be

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excused on the basis of its age, while the second deals with the installation of equipment assumed to be reliable.

Table 4 displays the characteristics of two exhibits, two bulletins, one military standard, and eight reliability specifications. The MIL standards, the bulletins, and exhibits outline programs. This is also true of the eight specifications but, in addition, they establish reliability requirements. Four of the eight specifications go an additional step; they outline reliability demonstration tests and provide penalties for failing the tests.

While this study reviews only two major specification categories (equipment and product assurance) for their characteristics pertaining to reliability, it is sufficient to show that reliability can be specified. At the present time, the most logical way to do this is by an MTBF figure given in the detailed specification and based on operational requirements and equipment complexity. As progress is made in the science of reliability, other criteria may be found to be more desirable. When reliability is specified, the costs assigned to it tend to increase. However, other costs, such as rework, decrease. Thus it is not at all obvious that reliability effort costs money; it may in fact save money.

REVIEW: This paper accomplishes its objective of helping to promote an understanding of military specifications pertinent to reliability and of the rationale behind them. Sufficient detail is given to adequately develop the points made by the author. It might be well to have similar examinations conducted in other important categories, but those given serve the purpose of the present work.

It is heartening to have a representative of industry say that good reliability and its specification may in fact not be expensive, when the broad picture is considered. The proper specification of reliability is fundamental to the attainment of reliable systems, and its achievement should be vigorously pursued.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Zeus resistors made at rate of one each 3 sec.

AUTHOR: James Trainor

SOURCE: missiles and rockets, vol. 9, no. 2, July 10, 1961, pp. 22-24

PURPOSE: To describe a unique computer-controlled production line for the manufacture of high-reliability carbon-deposited resistors.

ABSTRACT: Carbon-deposited resistors to meet stringent reliability and performance requirements for the Nike-Zeus anti-ICBM are being produced at the North Carolina Works of Western Electric Company. The production line is fully-automated and computer-directed, so that the resistors are untouched by human hands.

The resistors are designed to function under any and all environmental conditions with a rate of failure not exceeding one in 2×10^8 hours--a reliability far ahead of that achieved by conventional techniques.

Before setting up this automated production line the company made a detailed analysis to determine why resistors had failed in the past. The main reasons were found to be: (1) an aging effect due to inorganic material in contact with the resistor, (2) contamination due to human handling during production, and (3) the effect of moisture.

A brief description of the production line and its operation is given. The production sequence is described, with particular reference to two features, viz. gold capping for low contact resistance and the procedure for detecting leaks in the protective shell. The current acceptable yield of the process is given as 65% (resistance within $\pm 1\%$ of nominal value), but it is expected that this can be increased to meet or surpass the design goal of 85% acceptable resistor yield.

REVIEW: This paper describes and illustrates the steps taken by one company to produce a high-reliability component. It exemplifies the advice so often appearing in the literature to the effect that good reliability is achieved not by merely tightening up on quality control measures on conventional manufacturing processes, but by deliberately designing to avoid the causes of unreliability, leading to whole new manufacturing concepts where necessary.

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Washington 25, D. C.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimating the reliability of precision potentiometers

AUTHOR: Herbert Adise, President, Computer Instruments Corporation, 92 Madison Avenue, Hempstead, Long Island, New York

SOURCE: Electronic Industries, vol. 20, March, 1961, pp. 106-107

PURPOSE: To compare the reliability of wire-wound potentiometers with that of carbon film potentiometers, and to compare the reliability of a single wiper with that of multiple wipers.

ABSTRACT: (Covered by REVIEW, below.)

REVIEW: This paper is concerned with the estimation of the reliability of precision potentiometers, and proposes a means of deciding whether to use multiple wipers or single wipers. It also compares the reliability of wire-wound potentiometers with that of carbon film potentiometers. However, because of at least three basic fallacies the conclusions drawn are not substantiated by the arguments given.

The author states that the reliability of a component is the inverse of the probability of its failure. This is not in accord with the accepted understanding of reliability as the probability of success. While specific definitions of reliability may differ, the acceptable definitions have the word or concept of "probability" in common. Clearly the inverse of any probability is a number greater than or equal to one, and therefore cannot represent a probability. Thus the author is not using an acceptable definition of reliability.

The author reasons that for a single sliding contact since there are two possible cases (either it will or will not make contact), and one of these represents failure, therefore the probability of failure is 1/2. The fallacy in the argument is that it is valid only if the two possible cases are equally likely, and surely for a potentiometer of any merit this could not be so. This fallacious argument affects all four of the conclusions which are drawn.

Another fallacy in the paper is that a series of probabilities of supposedly mutually exclusive events are added to obtain a probability of failure of L/2, where L may take the integral values 1, 2, 3, ... Clearly L/2 may exceed one under these conditions, and therefore does not represent a probability. The fallacy here lies in the fact that the events in question are not actually mutually exclusive.

It would be interesting to see a reworking of this paper based on valid arguments. As it stands, no faith can be placed in the conclusions on the basis of the arguments given.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An analog approach to reliable transistor circuits

AUTHOR: H. T. Gruber, Battelle Memorial Institute, Columbus, Ohio

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 474-484, January, 1961

PURPOSE: To describe an analog computer for calculating transistor junction temperatures under any operating conditions.

ABSTRACT: While there are many initial causes for transistor failures, the final cause is usually overheating of the junction. Thus a computer for the calculation of junction temperature would assist in designing circuits which are more reliable. An analog computer was chosen for its simplicity and low cost. The transmission line equivalent thermal circuit is rather complex, so a series string of parallel RC pairs is used. The junction cooling curve can be considered made up of a large number of negative exponentials. In practice, a few terms will give the required accuracy. The cooling curves are determined empirically for each transistor type by using the collector leakage current as a thermometer. First, the steady state temperature-leakage is measured, then the cooling curve (leakage - time) is plotted, and finally the temperature vs. time cooling curve is computed and broken down into three exponentials. From the time constants and the circuit drive capabilities, suitable values are chosen for the circuit parameters. Time compression is used to keep capacitor values down. The complete circuit, including feedback for leakage heating, is shown. The proper procedure for simulating a finite heat sink is given for use when the assumed infinite sink is not realistic.

REVIEW: While the paper is more restricted than the title would imply (See PURPOSE), it is nevertheless interesting and potentially helpful in circuit design for reliability. In many cases potential thermal problems are ignored because ready means for solving them are not available; therefore this simple analog computer could be very helpful.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability--both a tool and objective in design

AUTHORS: S. N. Greenberg and S. Zwerling, Missile and Space Vehicle Department, General Electric Company, Philadelphia, Pennsylvania

SOURCE: Industrial Quality Control, vol. 18, July, 1961, pp. 21-25

PURPOSE: To summarize the method of reliability analysis used at MSVD of GE.

ABSTRACT: Reliability is a most important attribute of a product but it can only be measured when the product is in use. Design engineers must become reliability-conscious through education. At MSVD each design engineer is given the necessary instruction, manuals, and application data to be used in reliability analyses of his own design. He continually reviews his design for reliability as it progresses. A reliability figure of merit (RFM) is defined as the probability of survival in the intended use. The RFM, when based on components, is rather inaccurate and must be supplemented by tests. Seven steps are given for the reliability analysis.

1. List the components on the proper forms and fill in the required applications data. Improper selection can be disclosed here.
2. On the above forms fill in the failure rate, which is taken from the proper charts or graphs. The proper stresses must be used. Misapplication is shown here and can be remedied by derating, substitution, redesign, environmental isolation, redundancy, and/or wide-tolerance circuitry.
3. Compute the combined failure rates for redundant parts using techniques shown in the manual.
4. Total the failure rates for each circuit by adding the parts failure rates.
5. Apply a weighting factor to the circuit failure rate to reflect its importance to overall mission effectiveness. Reliability consultants are available for this.
6. Add the effective circuit failure rates, take duty cycle into account and convert to a reliability value. The exponential law is assumed.
7. When one-shot devices are used, their probabilities of performance are included by using the product rule of combination. The final result is the RFM.

All failure rates are evaluated at 90% confidence levels. Private analysis has shown that the overall confidence level is higher -- due to probability combinations. The RFM is the basic value upon which the design engineer judges the effectiveness of his design, selects among several competing designs, and evaluates his progress in achieving design goals.

Reliability values are initially apportioned on the basis of equipment

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

and circuit complexity; generally the number of active elements is used as a guide. After reliability estimates are made (as above), the failures allotted to each subsystem are reduced from the estimates by the relative amount the total estimate exceeds the total initial apportionment. This makes everyone go back to work to improve his subsystem, regardless of how well he met the initial apportionment. A block diagram and associated mathematical model for the entire system greatly aid this analysis.

REVIEW: The idea of having each design engineer concern himself with reliability is much better than trying to leave reliability to some "super-group." Although it may take more initial effort, the results should be superior. In general, the paper is easy to follow, although it suffers from incompleteness since it is a summary of a larger work. Wide-tolerance circuitry is apparently used only in case of necessity -- not as a general rule. Exponential failure rates are assumed for everything. The publishing of these reliability procedures is worthwhile since, in this way, different groups can compare, and thus improve, their own efforts.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the possibility of improving the mean useful life of items by eliminating those with short lives

AUTHORS: G. S. Watson and W. T. Wells, Research Triangle Institute, Durham, North Carolina

SOURCE Technometrics, vol. 3, pp. 281-298, May, 1961

PURPOSE: To find general conditions on a life distribution so that the mean remaining life of articles operated for some fixed test period is greater than the original mean life, to examine well-known life distributions in the light of these general conditions and to relate numerically possible increases in the mean remaining life to the fraction of the output rejected in order that an economic assessment may be made of the value of the method in practice.

ABSTRACT: When everything possible has been done to produce articles with long lives, there remains the possibility that a further improvement in the articles may be obtained by running them, for some time, under realistic conditions. The fraction that does not fail may have a longer mean remaining life than the original articles. In this paper conditions on the life distribution of the original articles are found which will insure this. The Weibull, gamma, exponential, extreme value, and log-normal life distributions are examined in detail. (Authors)

A sufficient condition for which initial testing will improve the mean useful life is that h(t), the conditional failure rate at time t (the hazard rate), steadily decrease as t increases. It is concluded that (i) no initial testing will change the mean useful life when the life distribution is exponential, (ii) initial testing will always increase the mean useful life when the life distribution is the Weibull with shape parameter less then unity, the gamma with shape parameter less than unity or the extreme value distribution, and (iii) when the life distribution is log-normal it is always possible to increase the mean life to any extent desired by continuing to test until a sufficiently large number of articles have failed.

REVIEW: The technique discussed in this paper is appropriate when the hazard rate steadily decreases. Thus the useful mean life of articles having certain life distributions can be improved by initial testing if the articles fail rapidly early in their lives and at a steadily decreasing rate as time passes or if after some point in time the conditional rate of failure steadily decreases. The paper shows that the initial testing procedure (or "burn in") may be used to advantage in situations involving life distributions which have the property of a decreasing hazard rate.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Designing NOR circuits for maximum reliability

AUTHOR: K. M. Trampel, IBM Corporation, Poughkeepsie, New York

SOURCE: Electronics, vol. 34, June 2, 1961, pp. 46-48

PURPOSE: To show how to design for worst-case conditions.

ABSTRACT: All logical expressions can be derived by using the NOR circuit. Thus, the design of a reliable NOR circuit is of importance. The one described here uses a PNP transistor with a grounded emitter. There are three inputs and the output is taken from the collector. When the transistor is ON the output is nominally zero and represents the number "0"; when it is OFF the output is negative and depends on the negative supply voltage, the collector resistor, and the output current. It is represented by the number "1." Since the transistor operates in a saturated mode, the speed is rather slow.

Worst-case design takes into account the degeneration of components, device specifications and circuit tolerances, and furthermore assumes that everything will deviate in such a way as to cause the most trouble for each phase of circuit operation. In this NOR circuit, for example, the input bias resistor is assumed to be on the high side for the OFF case and on the low side for the ON case. The Taylor criteria are used here, viz. all parameters, except the most critical are taken at worst-case purchase tolerance and the most critical one is taken at worst-case end-of-life tolerance. Transistor, resistor, and power supply specifications are given. The OFF case is easily solved by the application of electrical laws. The transistor leakage is considered the critical parameter. The ON case solution requires that a load current be given. The critical parameter is the load resistance of the NOR circuit. The use of simple electrical laws also solves this case. The results are several inequality relations and they are solved by trial and error. Finally, the voltage and power ratings of the transistor are checked.

REVIEW: This is a good example of the application of worst-case design. The use of the Taylor criteria is debatable, but one cannot afford complete worst-case design very often. Another approach is typified by the use of probabilities of parameter deviations and the assumption that the uncertainties are normally distributed. Both methods have advantages and disadvantages.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Research and development reliability (paper-back book, price $4.00)

AUTHOR: R. H. Myers, et. al., Technical Publications Committee

SOURCE: Electronics Division of American Society for Quality Control; February, 1961

PURPOSE: To provide a guide which emphasizes the engineering aspects of reliability and to outline reliability needs during the critical research and development (R & D) period.

Fifteen contributed papers have been selected from the literature and arranged into a book, consisting of four sections. Since the papers are rather independent, even within sections, they are abstracted and reviewed separately.

Part I. Requirements Phase

1. The nature and function of R & D; B. H. Klein, W. H. Meckling, and E. G. Mesthene

ABSTRACT: R & D is an uncertain business whose function is to buy knowledge; no one is sure just what knowledge will be obtained. There are four kinds of R & D: basic research, exploratory development, component development, and systems development. A particular program cannot be all planned at the start; each step must depend on the results of previous steps. The five rules of a good development policy are as follows.

1. The contractors must have a clear idea of the expected role of the system and must have a free hand to develop it as the early phases provide reliable test information.

2. There may be several possibilities initially under development--until one is finally selected as the best. This planned early duplication is economically sound.

3. Only modest financial commitments to a specific design should be made until test results are available that prove its soundness.

4. Those in technical charge of a program should have authority to take quick advantage of new information gained during testing.

5. At each stage, equipment should be tested as soon as possible. Only in that way can good performance be assured.

REVIEW: This is a qualitative paper directed toward administration.

* * *

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RELIABILITY ABSTRACTS
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2. Good specifications--key to reliability; R. E. Jones

ABSTRACT: The importance of good specifications to reliability cannot be overemphasized. Good specifications can and must be written early in a program regardless of whether the program is operated on a normal or an accelerated schedule. The problems of lateness, incompleteness, lack of clarity and lack of feasibility can be alleviated by active participation of the reliability organization in the planning of specification effort, the generation of the reliability and environmental portions of specifications, and the review of specifications, prior to release. The methods described in this paper have proven themselves quite effective at Bendix Systems Division. (Author)

REVIEW: This is a good summary paper for those concerned with specifications. The check list for reviewers is very good. Many articles, such as this, put great emphasis on the reliability group; the assumption is at least implicit that this group has better qualified, more experienced people than other groups.

* * *

3. Organizing dynamically for reliability; W. R. Kuzmin

ABSTRACT: A dynamic reliability organization should be composed of the following groups:

1. Statisticians who contribute information leading to more reliable designs.

2. Reliability applications engineers to interpret statistical analyses and suggest applications which are reasonable from an engineering point of view, and to determine when it is advantageous to test experimental designs by simulation.

3. A test lab responsible for efficient performance of experiments and the reporting of any test irregularities which could affect the reliability of a system.

4. Systems engineers to provide an overall viewpoint on the effect on total performance of any change in reliability of a component design.

The organization should provide for:

1. The physical location of statisticians among design and systems engineers in order to permit statisticians to become thoroughly familiar with the product or system. This will result in more realistic design of experiments and a reduction in the time necessary for the statisticians to understand the important factors of a product.

It will also provide engineers with first-hand information on the efficient use of statistics as a design tool.

2. The routing of any proposed design test through the reliability department so that it can be reviewed to assure that it meets its objectives, gives a maximum yield of information at lowest test cost. This will also give design engineers valuable information concerning reliability engineering and statistical concepts. (Author)

REVIEW: The message in this paper is more for those concerned with the organization and administration of a reliability group than for engineers engaged in design. It is interesting to note the emphasis which the author places on the realistic design of experiments, and the analysis and interpretation of the resulting data. This calls for close cooperation between applications engineers and statisticians. The proposed organization provides for this cooperation.

* * *

Part II. Systems Analysis Phase

1. Two-parameter lifetime distributions for reliability studies of renewal processes; B. J. Flehinger and P. A. Lewis

ABSTRACT: Several probability functions are defined: lifetime distribution, lifetime density, survival probability, hazard, expected number of replacements, and renewal rate. In the exponential distribution the hazard is constant; however, physical reasoning suggests that in practical situations the hazard increases monotonically with time. The Weibull, normal, log normal and gamma distributions all have an initial hazard of zero; this does not fit "reality" since a non-zero initial hazard is supported by much data. Three models are proposed. The first two have a hazard made from a constant plus, in one case a linear time term, in the other case a squared time term. These are the simplest models to fit the assumptions. The third model is a "truncated normal" distribution which has the truncation on the left rather than on the right. Renewal rates are calculated along with the other functions. An entropy is defined and used to measure the amount of randomness in each model. The truncated normal is found to be the most flexible; it can vary from completely random to completely determined, by making a suitable choice of parameters. Curves are shown for many of the functions.

REVIEW: This is a mathematical paper although some physical justification is given for the models. The introduction of an entropy as a measure of randomness is interesting. Since no application methods are given, the next step is to develop them and then to see how well real data fits each model. Because of the absence of indicated applications, this paper does not really belong in a "practical" book.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

* * *

2. System operational effectiveness (reliability, performance, maintainability); H. G. Friddell and H. G. Jacks

ABSTRACT: This paper recommends that equipment value be expressed in terms of "Operational Effectiveness" which is defined as an expression of the ultimate value of the equipment to the using organization and includes all factors which contribute to or detract from the accomplishment of the intended purpose of the equipment.

A procedure is presented for obtaining an Operational Effectiveness value for systems. To demonstrate this procedure, an effectiveness value is derived for a complex multi-mode system by combining the computed or measured values of system reliability, performance, and maintainability.

The results of the application of this procedure for maximizing the effectiveness of electronic systems are presented. (Authors)

REVIEW: This is an interesting discussion of the problems involved in trying to specify and measure the value of equipment to the user. The examples are quite informative and interesting. The use of probability to express "operational effectiveness" is reasonable, although no justification is given for using equal weights for the three phases. The concept introduced here probably deserves more follow-up than it seems to have had.

* * *

3. Some effects of redundancy on system reliability; H. S. Balaban

ABSTRACT: Redundancy must be understood if it is to be effectively applied. Some simple cases are discussed, such as series and parallel redundancy. Switching is introduced and imperfect switches are considered. The optimum level of redundancy is shown to depend on the reliability of both the components and the switching. One section is devoted to redundancy vs. improved elements. Conditional events are also discussed.

REVIEW: This is a good introduction to "real" redundancy for those who have only been exposed to a few simple cases. The problem is shown to be rather complicated when all factors are considered. The probabilities of survival of systems are compared as a function of time. This is superior to just comparing the mean lives of the systems.

* * *

4. Prediction of reliability; J. A. Connor

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

ABSTRACT: Reliability-prediction exercises, performed as an integral part of electronic equipment development, constitute an investment in engineering extrapolation. The statistical refinement of methods employed must be tailored to meet the need of a dynamic growth in product design while recognizing normal restrictions in pertinent facts, funding, and allotted time at each phase of development. It is assumed in this presentation that the vital character of reliability achievement has been fully established. Thus, it remains as a definitive task to tool-up and exploit appropriate methods supporting the design of reliability into electronic systems. This paper attempts to organize the methodologies of reliability prediction capable of a rapid, and immediate, application. Through this means it is contended that the basic strategies of electronic system and circuit design can be beneficially influenced, and techniques for monitoring reliability accomplishments can be made an integral part of electronic design engineering. Before presenting a set of organized do-it-yourself reliability prediction instructions, an introductory analysis is made of the character of the data from which sound prediction techniques can be synthesized. Basic principles are given as a necessary positive-thinking antidote to the obvious lack of a closed loop in the task of predicting the future from a fragmentary knowledge of the past and present. Computational routines, employing both the "part population" and the "individual parts-application" methods, are described and examples outlined. It is concluded that reliability predictions form a sound investment in product engineering, affording a superior level of visibility to both the design engineer and engineering management. (Author)

REVIEW: This is a comprehensive summary of the problems and philosophy of reliability prediction rather than a set of charts and tables for calculating reliability. Many of the "principles" are very helpful.

* * *

Part III. Design Phase

1. Circuit design concepts for high reliability; F. E. Dreste

ABSTRACT: "Out-of-tolerance" failures can be reduced by proper design. The "worst-case" method is difficult and sometimes wasteful. If normal distributions are assumed for component value variations, the circuit behavior can be statistically predicted. In general the part tolerances can be assumed to be $\pm 3\sigma$ limits. Several assumptions are made such as random selection and small percentage deviations from nominal values. High and low values caused by changes in the component value are treated separately. Equations for combining tolerances are developed, and several illustrative examples are worked out. In addition to out-of-tolerance failures, there are catastrophic failures. These can be minimized by proper component selection.

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REFERENCE: Fred E. Dreste, "A Reliability Handbook for Design Engineers", Electrical Engineering, June 1958, pp. 508-512.

REVIEW: It should be emphasized that the method presented for combining tolerances is, in general, an approximate method, strongly dependent on the assumption that the performance variable is approximately a linear function of the part variables. Of course, for the particular case when it is exactly a linear function, the method is exact. For a product, but not a quotient, an exact formula is available, which gives a larger variance than does the approximate formula. The method is decidedly preferable to design techniques which do not take into account the parameter variations and the probabilities associated with them.

* * *

2. Quantitative criteria for thermal evaluation of electronic equipment; T. C. Reeves

ABSTRACT: Mean temperature rise is a good measure of performance for free convection cooling. For forced fluid convection, the ratio of heat convectively removed to total heat generated measures the effectiveness. Maximum part temperatures are of use in predicting reliability. A thermal Figure of Merit can be defined as the ratio of mean life at conditions of interest to mean life with everything at ambient (or coolant) temperature. While all these criteria are useful, the last gives the most information on how well a cooling job has been done.

REVIEW: As the title says, this article discusses how to measure cooling effectiveness, not how to cool effectively. The criteria all seem useful and well founded.

* * *

3. Reliability through safety margins; R. Lusser

ABSTRACT: Components for missiles must be 100 times as reliable as for piloted aircraft and 100 x 100 times as reliable as for consumer products. This is because of the much larger number of vital components in the missile. A vital component is one whose failure results in disaster. It is impossible to get too much reliability. The use of safety factors in structures and machines is well known and accepted. The principle of safety margin is introduced. The safety margin takes into account the variability of materials and systems whereas the safety factor is concerned with averages. A good unit for safety margin is the standard deviation (σ). Safety margins of 10σ, 20σ or even more should be used wherever possible, and 5σ is a minimum. A table of contingencies and contingency margins is given. These are directly analogous to the uses of various safety factors. The prime responsibility for writing and complying with reliability specifications is with the R & D prime contractor.

RELIABILITY ABSTRACTS
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The contracting agencies also have a responsibility and some authority; a reliability code is suggested for their use.

REVIEW: This is a forthright paper that really comes to grips with some reliability problems. The author's outlook is on the side of getting all the reliability possible, rather than the minimum amount. Unfortunately, some of the goals may not be attainable without serious "trade-offs" and without drastic changes in the usual way of doing things. Reliability of the degree envisioned for missiles would also be welcomed by industry who don't want to employ electronics repair crews but do need electronic equipment. More papers of this sort would be a good spur for reliability development.

* * *

4. Briefing on report of ad hoc study on electronic parts specifications management for reliability; E. J. Nucci

ABSTRACT: This is a review of the "Darnell" report (reference 1). Electronic advances together with complex equipment which demands high reliability have created the need for (1) additional requirements and faster coordination of parts specifications, (2) distribution of valid technical data to design and logistics personnel, and (3) a complete review of the parts specifications program to ensure compatibility with the reliability program. These needs are included in the AGREE report. The task group to review these problems was a balanced team with experience in parts, tubes, semiconductors, equipment, and systems design.

Prototype specifications were prepared for paper dielectric capacitors, relays, and tubes. Normally four or five reliability levels are specified (in terms of failure rate) ranging from the highest failure rate presently specified down to 0.001%/1000 hr. Sampling, accelerating and calculating methods are presented. Procedures for documentation of actual part reliability are suggested. Full military and industrial coordination by the end of 1960 was recommended. Programs for parts data (including reliability and application) are suggested.

An advisory group on management of electronic parts specifications (AGMEPS) should report directly to the Assistant Secretary of Defense (Supply and Logistics) and should review all DOD programs on electronic parts specification development and technical documentation and the management thereof. The list of explicit duties of AGMEPS is long and specific. By the middle of 1961, the recommended procedures in specifications for essential items should be implemented. There is strong support in industry for the program, but the program, per se., is not the whole answer. It must be immediately and effectively implemented and backed up by research and development programs.

RELIABILITY ABSTRACTS
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REFERENCES: (1) "PSMR-1--Parts Specifications Management for Reliability, Vol. I and II" May 1960, available from Supt. of Doc., U. S. Government Printing Office, Washington 25, D. C. at $1.50 per copy.

(2) Report--"Reliability of Military Electronic Equipment" 4 June 1957 available from Supt. of Doc., U. S. Government Printing Office, Washington 25, D. C. at $1.75 per copy.

REVIEW: There is little to say that is not said in the report except to hope that the suggestions are effectively implemented and backed by R & D programs.

* * *

5. The measurement and specification of product 'abilities; J. A. Cafaro and H. D. Voegtlen

ABSTRACT: Customer satisfaction with equipment is determined by its reliability, repairability, supportability, serviceability, operability, producibility, and other factors. That these qualities are not being properly supplied to the customer is illustrated by the following facts about military equipment.

1. For each 1000 hrs. of operation, 3 primary equipment failures occur for each 1000 parts of equipment complexity.

2. Maintenance of 30 man hours for every 1000 operating hours for each 1000 parts is required.

3. One service pays $40,000/yr to support each 1000 parts, not counting capital investment.

These ills can only be corrected when we can identify, measure and control these product 'abilities. Detailed examples are given for each of the above 3 problems. To improve product 'abilities will require a concerted effort within industry and the military.

REVIEW: This is an interesting way of summarizing the problems that beset systems and equipment. The examples serve to emphasize the tremendous costs of poor reliability and the potential saving to be made by the availability of very reliable electronic equipment.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Part IV. Evaluation and Test Phase

1. A unique approach to reliability design reviews; R. S. Cazanjian

ABSTRACT: In order to insure adequate design reviews, we have developed a comprehensive manual which contains detailed checklists and design methods. The primary effort has been to encourage the development engineer to effectively review his design as it progresses. At various milestones in the development program, formal meetings are held to review the adequacy of his methods, not necessarily the design itself.

Design review conferences have grown less time consuming, with analytical computations rather than intuitive feelings forming the basis for discussions. The necessary ingredients for reliable designs have been more clearly defined, removing some of the previously experienced ambiguities. However, further areas of improvement for policies, procedures, checklists, and design methods are now being planned for the increasingly complex systems and severe development schedules anticipated in the near future. (Author)

REVIEW: This is a good paper on design reviews, although the uniqueness of the approach is certainly open to question. One item that might be explicitly added to the design reviews is to make the mechanical and electrical designs as "idiot-proof" as possible. Designers must learn to live with the fact that their systems will not be treated with the care they ought to have.

* * *

2. Probe testing--a tool for reliability; H. W. Price

ABSTRACT: In generalized stress space the specifications form an n-dimensional rectangle, while the performance is usually quasi-ellipsoidal (also n-dimensional). To test at all possible "corners" of this "rectangle" would be a long task; so a method of probe or spot testing is suggested. The stresses are divided into 2 parts, those where the case provides all the protection (e.g. corrosion and humidity) and those where it does not (e.g. temperature, voltage). The "rectangle corners" which are most likely to produce failure are listed and then several random orderings are made. The test units are sequentially submitted to all conditions of one ordering of the list, a different order for each sample. If the "rectangle corners" lie well inside the "quasi-ellipsoid", the chances are that the equipment is good; if they lie outside the equipment is not good. A description of the selection and analysis techniques is given.

REVIEW: This is a good system for "spot checks" when limited facilities are available. The systematic approach is much more likely to produce good

results than would the more usual intuitive methods.

* * *

3. Estimation of reliability from incomplete data; G. R. Herd

ABSTRACT: This paper presents some of the available methods of estimation for the survival probability and, consequently, the mortality probability under situations where the observational units yield incomplete information. A number of such statistical methods are described and illustrated with life-testing examples. Three types of incomplete or censored data are considered: loss of information occurring at fixed intervals, losses occurring at certain random events, and losses occurring at random in time and quantity. Nonparametric methods are discussed as well as certain parametric cases. (Author)

REVIEW: This paper should be helpful to those engaged in life testing. It presents the appropriate equations and examples of their use. References are given for those who wish more information.

* * *

OVER-ALL REVIEW

Eight of the fifteen papers are from the Fifth and Sixth Symposia on Reliability and Quality Control (1959 and 1960 respectively). Most of the other papers have been published elsewhere in the literature. The material as such is therefore not new.

The book is an interesting collection of papers from the literature, but would not seem to serve the need which exists for a handbook covering engineering and other aspects of reliability. It would be preferable to have each section summarize the principal knowledge in the area with which it deals, with emphasis on descriptions of useful techniques. It would be desirable also to have the sections coordinated with one-another.

This collection will probably be of more use and interest to those who are in administrative positions, than to those directly involved with the design and analysis of reliable systems.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A check list for design review (two parts)

AUTHORS: Bruce D. Smith and Irving M. Aptaker, RCA, Burlington, Massachusetts

SOURCE: Electronic Design, vol. 9, May 24, 1961, pp. 36-39; and June 7, 1961, pp. 60-63

PURPOSE: To provide designers with a comprehensive check list to help them avoid errors of both omission and commission.

ABSTRACT: The main headings are:

Electrical Design: Parts Application, System & Circuit Considerations, Reliability Analysis, Safety Factors, Maintenance, Electrical Interference.

Mechanical Design: General Design, Workmanship & Maintainability, Materials & Processes.

Human Engineering

Value Engineering: Specification Review, General Production Costs, Electronic Design, Mechanical Design, Standardization, Maintainability Design, Testing, Subcontract Items.

REVIEW: This is a reasonably complete review for the circuit designer. One disadvantage is that some questions should have "yes" answers and others have "no" answers; less experienced engineers may not know which. At least one item--removal of soldering flux--is controversial. In mechanical design, no explicit mention is made of fatigue of the parts. Although it is implicit in some items, no explicit mention is made of "fool-proofing" the system, that is, designing for handling and use by those who do not follow instructions carefully. Many groups might wish to compare this list with their own to see if they should add some items.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Contractors trading reliability data

AUTHOR: Leon H. Dulberger (Assistant Editor)

SOURCE: Electronics, vol. 34, June 2, 1961, pp. 20-21

PURPOSE: To comment on and publicize a program for exchange of reliability data among military contractors.

ABSTRACT: An operation which circulates reliability data is Interservice Data Exchange Program (IDEP). It supplements, by being much faster, the Mil specs. Individual companies submit reports of their experience with components (such as transistors, resistors, relays--over 90 items in all) to the program center which distributes the information in a standardized way. The component vendor is given advance notice of a report and an opportunity to comment on it. All reports are unclassified and are available to any vendor from the Armed Services Technical Information Agency in Washington, D. C. The program is expected to give designers insight into the component state-of-the-art, to provide handbook-type data for new designs and to provide information needed to prepare reliability analyses on new systems. While there is much favor in industry for the program, some firms are rather cautious about their statements on it.

REVIEW: The more complete and up-to-date data that the designer can have about the actual performance of parts, the better job he can do. In the absence of good information, about all he can rely on is vendors' advertising claims. This IDEP information should be made publicly available for all to use. Perhaps it might boost the quality of advertising. Those who are interested in it are urged to write for further information to the Armed Services Technical Information Agency (ASTIA), Arlington Hall Station, Arlington 12, Virginia.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of parallel systems with repair and switching

AUTHOR: S. G. Kneale, Chief of Technical Analysis and Planning, Electronics Division, Avco Corporation, Cincinnati, Ohio

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 129-133, January, 1961

PURPOSE: To evaluate the effects of switching on the mean-time-to-failure of redundant systems, and to evaluate expressions for the reliability of such systems.

ABSTRACT: A redundant system, consisting of n parallel subsystems, is considered. It is assumed that each subsystem has a constant failure rate λ_o and a constant repair rate λ_1. The case where all "non-failed" elements are "on", and subject to the failure rate λ_o and all failed elements are under repair, is considered in Section I. An analysis using a discrete time Markov chain is made to give the mean time before system failure, which occurs when all n subsystems fail. Corresponding results are quoted for the case where switching is employed and only one element is subject to failure. For $\lambda_1 \gg \lambda_o$ an approximation to the mean time to failure is found in each case and these are compared on the basis of their ratio.

In Section II the differential equations for the state probabilities of the chain are used to evaluate, in principle, the system reliability for the case of no switching. It is stated that computer programs exist for their solution, and an approximation is given for $\lambda_1 \gg \lambda_o$. The corresponding approximate result, in the case of switching, is quoted.

REVIEW: The methods used are the usual ones for the analysis of such problems as contained in standard works. The analysis is well done and the matrix algebra is elegant. A novel feature is the introduction of the (n+1) th state in order to distinguish clearly the first passage time of the system to the n th state. The exact result for the reliability implied by the equation $1-R(t) = \int P_{n-1}(t)dt$ (which incidentally hardly needs the derivation given) is likely to be of less use than the approximate expressions. In fact the most useful practical results given are the approximate ones. For example the ratio of the mean time to failure when switching is used to that when no switching is used is given as n!, which shows the benefit to be obtained by using switching. In summary, the analysis is standard in method but has some novel features and provides approximate results which should prove useful in practice.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability check list for design engineers

AUTHOR: E. G. Fonda, Research Reliability Specialist, Missiles and Space Division, Lockheed Aircraft Corporation, Sunnyvale, California

SOURCE: Electronic Equipment Engineering, vol. 9, no. 6, June, 1961, pp. 21-22

PURPOSE: To provide a reliability checkoff list for engineers engaged in design.

ABSTRACT: This worksheet has been conveniently arranged into a checkoff list for engineers who wish to retain the list along with pertinent design data and test results in their design handbooks. The list is by no means complete in its present form but is suggestive of the questions normally concerned with and covered in reliability design reviews of various subequipment modules. (Author)

The article consists of the above paragraph and the list, including some 31 items.

REVIEW: The value of this list to a design engineer would depend a lot on the applicability of the various points to his specific project. However, it might well suggest one or more items which would otherwise be overlooked.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analyzing failure rates in electronic components

AUTHOR: G. W. A. Dummer, Royal Radar Establishment, Great Malvern, England

SOURCE: Electro-Technology, vol. 67, February, 1961, pp. 89-92

PURPOSE: To point out kinds of failure mechanisms for some electronic components and to list the failure experience at Harwell.

ABSTRACT: Fault (failure) rates of components are best obtained by observing equipment in operation. Severe operating conditions cause higher failure rates. The experience at the Atomic Energy Research Establishment at Harwell, England is summarized in two tables. An interesting point is the decrease in failure rates from 1949 to 1954/1955 and the increase thereafter for some components (1957 is the last year in the table). One explanation is increased severity of application around 1954/1955.

Failures due to production and use variables are described for several components.

Fixed Resistors

Carbon composition: Most failures are at the center of the rod. Open circuits can be caused by thermal overloads or mechanical failure. Resistance tends to decrease with time.

Pyrolytic or Cracked-carbon: Most failures are in resistance values over 100K ohms.

Wirewound: Open circuiting is the most common failure. It can be caused by poor welding, electrolytic corrosion and crystallization of the wire.

Variable Resistors

Carbon composition: The most common fault is noise due to bad wiper contact. Open circuits can be caused by poor end connections.

Wirewound: High power, low resistance units are quite trouble-free. When fine wire is used it may corrode and fail. Humidity and high voltage in combination are very bad.

Fixed Capacitors

Low-voltage paper: High leakage currents due to deterioration of impregnant are the main failure cause. Voltage surges may cause shorts or burnouts. Aging is also bad.

Molded silver mica: Conducting material may build up across the dielectric or the silver may migrate over the surface; both can cause failure. Corona in the presence of moisture is very bad.

Silver Ceramic: Silver migration adversely affects this type too.

Electrolytic: Electrolyte leakage is now rare. High and low temperatures are bad. Surges over the working voltage may cause repeated sparking. Solid tantalum capacitors may have spurious 2 to 5 microsecond pulses.

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Connectors
Circular multi-pin ones are being made more rugged; contact troubles are rare. Unsealed connectors may have flash over. Other types do have contact troubles and many can have mechanical failures.

Relays
Fine wires may corrode and open-circuit. Fatigue can occur in the suspension system. Both sealed and unsealed relays can have contact malfunctions, although from different causes.

Switches
Toggle switches have two troubles: fatigue failure of the main dolly spring and loss of tension on the wiper springs. Wafer switches with multiple contacts may have too low surface pressure.

Transformers
Standard, hermetically sealed units are quite trouble-free unless they are overloaded. Poor impregnation in unsealed types will eventually result in loss of insulation resistance.

A table is given of expected failure rates under laboratory and under computer conditions.

REVIEW: An article about English experience is very interesting. The listing of failure mechanisms can be of help to the circuit designer, especially if he is using redundancy. (Notable omissions from the list are tubes and transistors.) A more comprehensive survey which would give actual statistics on the failure causes would be very helpful. Many of the failure rates are ten times as high as those in a table given in the reference below.

REFERENCE: "Reliability growth prediction during the initial design analysis", Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 380-393, January, 1961 (See Abstract and Review Serial Number 12.)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimates of bounded relative error for the mean life of an exponential distribution

AUTHOR: Benjamin Epstein, Wayne State University and Stanford University

SOURCE: Technometrics, vol. 3, pp. 107-109, February, 1961

PURPOSE: To find an estimation procedure for the mean of an exponential life distribution, such that the estimate has a small relative error.

ABSTRACT: This paper shows how to obtain an estimate of the mean of an exponential life distribution such that the estimate is, with some preassigned confidence ($1-\alpha$) within a certain percentage ($100\delta\%$) of the true but unknown mean. The procedure requires the observation of a suitably large number of failures, r. The determination of r for certain values of α and δ is given. It is shown how one can compute, for any preassigned r, the confidence level of an assertion associated with the true mean life. Two numerical examples are given.

REVIEW: This paper is a contribution to the mathematical theory of life testing based on the exponential distribution. At least one of the examples given should prove helpful in indicating the types of problems which the procedure may be used to solve. This example is as follows: "How many tubes should be tested in order that there is a probability of at least .90 that the estimate is within 10% of the true mean life?"

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Multi-component systems and structures and their reliability

AUTHORS: Z. W. Birnbaum*, J. D. Esary, and S. C. Saunders, *University of Washington and Boeing Scientific Research Laboratories

SOURCE: Technometrics, vol. 3, pp. 55-77, February, 1961

PURPOSE: To investigate mathematically the combinatorial properties and reliability of general classes of multi-component systems.

ABSTRACT: Certain recent publications have dealt with problems of analyzing the performance of multi-component systems and evaluating their reliability. Moore and Shannon (1956) have presented a comprehensive theory of two-terminal networks. In addition to other results, they have developed methods for obtaining highly reliable systems using components of low reliability. Some of their procedures are credited to von Neumann (1956). Several of the concepts and results of the present paper are generalizations of the corresponding concepts and results of the Moore-Shannon paper. A discussion of complex systems interpreted as Boolean functions has been given by Mine (1959).

The present study deals with general classes of systems which contain two-terminal networks and most other kinds of systems considered previously as special cases, and investigates their combinatorial properties and their reliability. These classes consist, with several variants, of systems such that the more components that perform the greater the probability that the system performs. For such systems it is shown that, if each component has reliability p and the reliability of the system is denoted by h(p), then under mild additional assumptions the graph of h(p) vs. p is S-shaped. This means that there exists some critical value of p such that above that value the reliability of the system is greater than the reliability of a single component and below that value it is smaller. For p small the system has a reliability comparable to that of a series system, and for p large to that of a parallel system. By repeatedly iterating the system, i.e, by using replicas of the system instead of single components, one obtains systems with reliability arbitrarily close to 1 if one starts with component reliability above the critical value, but with reliability arbitrarily close to 0 if one starts below that critical value.

REFERENCES: E. F. Moore and C. E. Shannon (1956), "Reliable circuits using less reliable relays", Journ. of the Franklin Institute, vol. 262, pp. 191-208.

J. von Neumann (1956), "Probabilistic logics and the synthesis of reliable organisms from unreliable components", Automata Studies, pp. 43-98, Annals of Math. Studies No. 34, Princeton University Press.

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Hisashi Mine (1959), "Reliability of physical system", IRE Transactions, PGIT, vol. IT-5, Special Supplement May 1959, pp. 138-150.

REVIEW: This paper is a contribution to the mathematical theory of reliability. The results are carefully developed, and the assumptions on which they are based are clearly stated.

From a practical point of view, it must be borne in mind that the obtaining of structure and reliability functions which accurately represent the state of the structure may be a difficult task for a complex system. Another limiting factor, insofar as applications are concerned, will often be the lack of adequate data on the reliability of components. These remarks are not, of course, intended to detract from the value of the paper as a mathematical contribution.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Circuit design reliability predictions

AUTHOR: --

SOURCE: Electronic Equipment Engineering, vol. 9, no. 7, July, 1961, p. 28

ABSTRACT: An analysis has been made of the probable reliability of the circuits published in Electronic Equipment Engineering Circuit Design Awards Program, January through April of 1961. The analysis, made by Henry Hall of the Reliability and Quality Assurance Department of Sylvania's Waltham Laboratories, was based on RCA Technical Report TR-59-416-1. The procedure is listed in tabular form for one design, and final results (MTBF values) are quoted for the other entries.

REVIEW: Those wishing more detail on the methods used will want to consult RCA Technical Report TR-59-416-1. The article is essentially a listing of the probable MTBF values for the circuits mentioned.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Derating--its meaning and limitations

AUTHOR: J. R. Isken, Manager, High-Reliability Resistor Project, International Resistance Company, Philadelphia, Pennsylvania

SOURCE: Electro-Technology, vol. 67, June, 1961, pp. 80-83

PURPOSE: To show that safe and practical derating of components is not a simple matter and to review current practices for resistors.

ABSTRACT: Derating may have any one of three meanings: (1) to reduce the dissipated power (so that ambient temperature may be increased above rate), (2) to reduce the ambient temperature (so that power dissipation may be increased above rate), and (3) to reduce both the ambient temperature and dissipated power (so that performance will be improved). The author reviews current derating practices in the light of resistor problems, and makes suggestions for obtaining more realistic and useful results.

Three problems which are encountered are (a) derating practices vary between resistor manufacturers, (b) usually only the end points of the derating curve are given, and (c) end points are very often not properly defined in military specifications or in company standard practices. In the absence of data on intermediate points, it is customary to assume a straight-line derating curve, which may not be entirely accurate. The proper interpretation of any derating curve requires a knowledge of the manufacturer's criteria for his ratings. If the main criterion is failure-rate level, it is necessary to know how this level is defined.

In the derating of temperature it is important to remember that increasing the power also increases other stresses such as voltage gradient and thermal shock. These are not generally rated by the manufacturer, and it is virtually impossible for the customer to determine the right answers.

Increased life or reliability through reduced power and temperature is qualitatively good. However, the necessary documentation of failure rates would require a massive testing effort at considerable cost. It is necessary to assign a dollar value to the information, in order to develop a program whose cost is compatible with its value. The essential difference in programs of varying dollar values lies in the levels of risk associated with the conclusions. The author states that there may be no difference in the validity of high-risk and low-risk conclusions, that the difference lies only in the risk, which must be evaluated in terms of cost.

A discussion is given regarding three of the most important failure-inducing stresses. These are: temperature, voltage between adjacent

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

current-carrying paths, and voltage gradient along the current path. The opinion is stated that decisions on derating should be made only by the part supplier or as a result of a program closely coordinated with the part supplier. Mutual understanding and cooperation between user and supplier are essential.

REVIEW: Some of the points are merely repetitions of warnings that appear from time to time, although that does not decrease their value. This subject is not usually covered in an engineer's schooling and it can very easily be overlooked. Part of the problem could be solved if manufacturers would spend the time and money to get, and to publish, more than just one rating. They might also spell out the criteria for the ratings in all cases. The ratings and criteria should appear in the advertising material directed to engineers, since this is where they acquire some of their implicit knowledge.

The statement that there may be no difference in the validity of high-risk and low-risk conclusions (see ABSTRACT) is rather misleading. Empirically-based conclusions (such as the failure rate curves mentioned by the author) can never be said to be either valid or not valid. They are properly stated by giving the degree of confidence on which they are based, or the level of risk associated with them. Conclusions may be drawn from test and evaluation programs involving various levels of effort. However, the degree of confidence which one may place in the conclusions depends in general quite strongly on the level of effort. It should be remembered that estimated reliability is tied to the degree of confidence just as surely as cost is associated with level of effort.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Statistical analysis of logic circuit performance in digital systems

AUTHORS: E. Nussbaum, E. A. Irland, Bell Telephone Laboratories, Murray Hill, New Jersey; C. E. Young, International Electric Corporation, Paramus, New Jersey

SOURCE: Proceedings of the IRE, vol. 49, no. 1, Special issue on computers, pp. 236-244, January, 1961

PURPOSE: To review methods for combining the statistical distributions of a set of component characteristics to obtain the distributions of the system performance characteristics; to relate the results to transistor resistor logic and other circuits.

ABSTRACT: A digital system usually contains large numbers of relatively few basic circuit configurations. The over-all performance of such a system is largely limited by the characteristics of these building block circuits. If these characteristics (speed, logical gain, noise margin) are treated on a statistical basis as opposed to a worst case approach, substantial improvements in logical design flexibility may be attained.

This paper reviews methods for combining statistical distributions of a set of parameters to obtain the distributions of the performance characteristics. Both algebraic and numerical (Monte Carlo) methods are considered. Transistor resistor logic circuits are then analyzed in more detail. Resultant distributions of propagation delays and logical gain are obtained as functions of circuit parameter distributions, logical configuration and temperature. Comparisons with worst case design figures are made to indicate the extent to which statistical techniques improve predicted performance. In addition, some new circuit configurations, proved usable by statistical analysis, are shown to lead to greater economy and reliability. (Authors)

The approach taken is that of an engineering solution to the problem, rather than a rigorous statistical treatment. The algebraic method consists of expanding the system characteristic (y) into a Taylor series around the mean values of the component characteristics (x_i), assumed uncorrelated. Assuming the higher-order terms of the series to be insignificant in the region of interest, they are neglected.

This approach is applied to a simple voltage divider circuit, and the results are compared with those of worst case analysis. A Monte Carlo approach is described and applied to the same example. It is found to yield results with a larger standard deviation than that of the results of the algebraic approach. In addition to the statistical analysis of transistor resistor logic circuits, three further examples of the application of the results are given, viz. A--Propagation Delay,

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B--Pulse Shrinkage, and C--New Circuits.

REVIEW: This paper is a competent review of statistical techniques for estimating system reliability from component reliability. While the viewpoint is that of an engineering treatment rather than that of a mathematically rigorous derivation, commendable care is taken in pointing out the required assumptions, and the limitations which they impose. The authors compare the approximate Taylor series procedure with the more exact results obtained by the large-sample Monte Carlo technique. This is extremely valuable information which is usually not provided.

In order to apply the Taylor series approach one must know the form of the function relating the system characteristic (y) to the component characteristics (x_i). One must also have data on the distributions of the x_i. In complex systems these facts will present rather severe limitations. However, the breaking down of a complex system into groups of subsystems may help. The analysis might then be applied to the subsystems with a view to synthesizing a result for the overall system. Much depends, of course, on the system complexity. In any event, the present paper is a useful review of available statistical techniques.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The long-term stability of fixed resistors

AUTHOR: H. F. Church, Electrical Res. Assoc., Leatherhead, Surrey, England

SOURCE: IRE Transactions on Component Parts, vol. CP-8, no. 1, pp. 31-40, March, 1961

PURPOSE: To present the results of a study of the long-term stability of several types of fixed resistors.

ABSTRACT: The causes of long-term failure under practical conditions of use or storage of different types of fixed resistors commonly used in electronic equipment are reported. Tests for long-term resistor stability are critically discussed. Results of long-term life tests are graphically presented.

Carbon composition resistors under load fail by slow thermal degradation of the resistive material. Drift of value may also occur if unloaded resistors of this type are stored in a damp atmosphere. Vitreous enamelled wire-wound resistors made with fine wire may fail during tropical exposure both unloaded and especially when lightly loaded with direct current. High-stability cracked-carbon resistors may fail rapidly under light dc load by electrochemical action if moisture condensation occurs and the protective paint or varnish coating is inadequate.

REVIEW: This paper should be of special interest to those engineers who are involved in reliability work wherein it is necessary to know the expected long-term variation of different types of fixed resistors. The information should also be useful for worst case design analysis, etc. As stated by the author, the information presented is limited by the fact that many new types of resistors have come on the market in recent months and the type of testing carried out requires many months to produce significant results, thereby producing a considerable delay between the marketing of the components and the availability of the long-term stability information.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Prevention of the catastrophic failure of electronic systems by the use of linear discriminants on the system components

AUTHOR: Robert C. Bunce

SOURCE: Reliability Engineering Document No. 1, 83 pp., Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, April, 1961

PURPOSE: To present a statistical method, utilizing multiple measurements on a single component of an electrical system, for constructing a single criterion to aid in deciding by inspection sampling whether or not to accept a component.

ABSTRACT: Linear discriminant analysis is commonly set forth as a statistical tool which an observer can use as an aid in deciding to which of two multivariate populations an observational vector of multiple measurements belongs. The restrictive assumptions in the theory of the analysis as presented here are that the populations represent correlated normal distributions of random variables and that these distributions differ only in their mean vectors (location vectors).

In this paper the observational vector is a set of pre-life test observations on an electronic component. The populations of interest are the manufactured components which fail catastrophically in the field and those which perform acceptably in the field. The three step method used to determine the best linear discriminant can be described briefly as follows:

1. Select a random sample of the components and measure the meaningful electrical properties (parameters) of each member at the start of a life test (usually of the accelerated type).

2. At the conclusion of the life test separate the members of the sample into a discrete empirical distribution with three classes: (i) superior components which completed the test successfully and in all respects remained within performance specifications, (ii) average components which completed the test successfully but deviated in some respects from performance specifications, and (iii) inferior components which either failed during the test or demonstrated a tendency toward failures (a three standard-deviation-or-more departure from specified performance). Classes (i) and (ii) can be combined into a single class representing acceptable components. This two class division is more amenable to the discriminant analysis.

3. Construct the linear discriminant function using the pre-test data associated with the post-test subgroupings. The weights of the function are obtained by maximizing the distance, in sample standard units, between the estimated mean vectors of the two discriminant

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populations.

A critical point for dividing the resulting samples of numerical discriminant values into groups indicating acceptable components and non-acceptable components is derived from considerations of the desired field reliability of the component. A derivation of approximate confidence limits on the realized reliability of a system of many types of components selected by the discriminant procedure, a detailed example of the application of the procedure to transistors, and a short discussion of the application of the method to attain reliability requirements for Jet Propulsion Laboratory spacecraft complete the paper.

REVIEW: This paper extends the development of an interesting idea published in several Battelle Memorial Institute research reports. The successful combination of multiple measurements to form an inspection criterion would be a considerable contribution to reliability methodology. This appears, at first glance, to have been achieved here; however, a more careful investigation of the author's presentation suggests that the excellence of the results is due to the careful component testing under severe stress conditions and the initial differentiability of component reliability, rather than to the discriminant procedure. In general, it is unlikely that discriminant analysis will succeed if the populations being investigated cannot be separated by examination of the individual variates.

There are several errors and oversights in the presentation which the reader should keep in mind. The author's opinions that the method is "exceedingly accurate," and that the results are usually good for small samples, will not be shared by many statisticians. The elaborate discussions about normality assumptions throughout the paper are often contradictory in the sense that one normality assumption sometimes will preclude the existence of the next. Usually this is noted by the author in his discussions of the "nearly normal" distributions encountered in practice. The fact is that much of the discussion about normal distributions is not essential. Following H. Fairfield Smith's procedure of constructing a plant discriminant function, one can maximize the expected distance between discriminant values in the superior and inferior subgroups and obtain a set of weighting constants which are estimated by those given in this paper. Normality is essential only for testing whether or not the two subgroup populations differ in their mean vectors; this can be done successfully with the use of Hotelling's T^2 statistic (which is referred to in the paper as an F statistic with appropriately adjusted degrees of freedom). When the test sample is large, the same test statistic should serve as a good approximate test if the distributions do not depart far from the normal.

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There is one procedure given in the development of the discriminant function which will be difficult to justify by theoretical considerations. The author constructs empirical distributions of each variate within the subgroups. If these empirical distributions are not unimodal, he separates the variate into subvariates each having a unimodal empirical distribution. As a result, one idealized population in the classification system can have more variates than the other. The pitfalls to which this could lead are unknown and probably are very difficult to ascertain.

The sections dealing with reliability requirements include unstated assumptions which are not realistic; however they are often made and considered acceptable in the engineering literature.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electronic components for computers--determination of failure rates

AUTHOR: L. Knight, A.M.I.E.E., Reliability Department, I.C.T. (Engineering) Ltd.

SOURCE: Electronic Technology (London), vol. 38, pp. 214-216, June, 1961

PURPOSE: To discuss the determination of failure rates for electronic components used in computers.

ABSTRACT: Components may have degradation failures or catastrophic failures. It is desirable to consider these two types of failure separately. Degradation failures depend on the way the component is used; thus tests should be run under computer conditions, i.e. $40 \pm 5^{\circ}C$, ambient humidity and 20 hours duty per 24 hours. Usually it is found that the parameters have a near-Gaussian (normal) distribution. One example each of a capacitor and resistor test are shown and discussed. With thermionic valves (electron tubes) the life is rather short compared to that of other components, so that they have to be replaced during the lifetime of the computer. Sometimes a function of a parameter, such as the logarithm of transistor leakage, is normally distributed.

Catastrophic failures may be studied by accelerated tests, provided that such tests can be related to normal operating conditions. Modest tests under actual conditions may show up some manufacturing difficulties. The effect of high voltage on capacitor life is known so that accelerated tests are possible; a curve is shown. Connector tests can be accelerated in a reasonably predictable way by using extra-corrosive atmospheres, since these components usually fail as a result of corrosion of the mating surfaces due to atmospheric contamination.

REVIEW: This paper reports on some laboratory tests for the determination of the failure rates of electronic components used in computers. Emphasis is placed on the simulation of typical computer conditions, and the need for testing representative samples of the components to be used. This emphasis is a commendable feature.

The curves used to depict the conclusions in terms of confidence limits about the mean rest heavily on the assumption of normality (Gaussian distribution). This assumption will be satisfied approximately at best, and some doubt should be cast on conclusions drawn on the basis of 4σ limits, since these are so far out in the tails of the curve.

It is interesting to note that the relationship between the catastrophic failure rate and the applied voltage (as a fraction of rated voltage) for capacitors is shown as approximately semi-logarithmic.

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RELIABILITY ABSTRACTS
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This should be compared with the power law which states the D.C. life of a capacitor varies inversely as a power of the applied voltage (see Abstract and Review Serial Number 5). A check against actual data would be appropriate in assessing the merits of these assumptions.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A preliminary investigation of the steady and progressive stress testing of mica capacitors.

AUTHORS: H. S. Endicott and J. A. Zoellner, General Electric Company, General Engineering Laboratory, Schenectady, New York

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 229-240, January, 1961

PURPOSE: To discuss the theory for and to report some results on steady vs. progressive stress testing of mica capacitors.

ABSTRACT: A method of testing components by progressive stress rather than the conventional steady stress technique is presented. A mathematical concept relating the damage at failure to voltage and time is developed. A large scale application of the method to the life testing of mica capacitors is described and the results analyzed in terms of the theoretical model. There is a discussion of the advantages of the method, its limitations and some of the factors influencing the results. (Authors)

The "progressive stress" technique was suggested by recent work in the fatigue of metals and plastics. References to this work are cited, and briefly reviewed. A working hypothesis based on a concept of "accumulated damage" is set up. This hypothesis states that the amount of damage accumulated is proportional to the time integral of some power of the applied voltage at a given temperature. A corollary of the working hypothesis leads to a relationship between the time necessary to cause a given amount of damage under a steady stress and the time necessary to cause the same amount of damage under a progressive stress. The corollary is formulated in terms of ordered times-to-failure, and its validity is tested by applying the χ^2 goodness of fit technique for testing the hypothesis that two samples come from the same multinomial distribution.

Extensive tests were run on mica capacitors rated at 510 pf $\pm$ 5%, 300 dcwv, 125°C. Tests were conducted at 125°C, 147°C, and 200°C. In the case of progressive tests, rates of rise equal to 0.08, 2.2 and 7.0 volts per minute were used at the three test temperatures. Details regarding the tests and a schematic diagram of the equipment are given.

Unanticipated factors affected the results, so that the complete analysis could not be made. In general, however, encouraging results were obtained. The value of the power in the working hypothesis was found to vary with temperature, being largest at the lowest aging temperature. The results for the fastest rate of rise were consistent

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with those for the slower rates and with the steady stress results at much lower voltages. This indicates that a short test for acceptance or quality control is feasible. Complete data could be obtained in less than 24 hours.

REVIEW: This is a well-conceived and well-executed program which should be of interest even outside the capacitor field. It is interesting to note that the authors were aware of developments in mechanical fatigue (a rather unrelated subject). The planning was comprehensive, but unexpected effects showed up to make the analysis difficult. If these tests and ideas are extended, the following points might be kept in mind.

1. In the graphs, the scale for time of "progressive" failure is rather compressed and some relationships may be obscured.

2. Data from greatly accelerated tests suffer from two extrapolation difficulties, viz. (a) the model may not fit over the whole range, and (b) the calculated parameters are uncertain and therefore cause uncertainty in the extrapolation.

3. In the referenced method of fatigue testing, progressive stress is used to predict the fatigue or endurance limit by plotting failure stress vs. some function of the stress rate. Nothing like that is done here; thus the connection with the referenced method is rather tenuous.

4. More could be said about failure mechanisms.

5. The value of the power in the working hypothesis may be a function of capacitance value.

6. The constant of proportionality in the working hypothesis might be evaluated and the distribution of the total damage at failure might be investigated.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Digital-circuit reliability through redundancy

AUTHOR: Albert A. Sorensen, Research and Development Division, Space Technology Laboratories, Inc., Los Angeles, California

SOURCE: Electro-Technology, vol. 68, July, 1961, pp. 118-125

PURPOSE: To present an analysis of digital circuit reliability improvement through part and circuit redundancy techniques.

ABSTRACT: In electronic circuitry it often becomes necessary to improve the system reliability beyond the point achieved by the simple techniques of derating, lowering environmental requirements, selecting better parts, etc. For this purpose the technique of redundancy is often used, and lends itself well to digital circuit applications.

This paper discusses two general approaches to redundancy, viz. (a) redundancy at the parts level, and (b) redundancy at the circuit level. Application of each approach to representative digital circuits, and analysis of the resulting improvement in reliability is considered. The advantages and disadvantages of each technique are briefly discussed.

The computation of the failure probability of a completely part-redundant flip-flop circuit is treated in detail. The calculated results show this circuit to be approximately 300 times better than the non-redundant flip-flop for the same length of time (assessed in terms of failure probability). A reversible counter circuit is treated in the same manner. Disadvantages of this type of redundancy are: initial checkout of the equipment is difficult, and the circuit must be designed to operate with considerable variation in parameters.

Illustrations of the circuit redundancy technique are given and the failure probability of a circuit-redundant non-reversible counter is calculated. The disadvantages of circuit redundancy are: smaller improvement in reliability; greater increase in size, weight, and number of parts; and increased power requirements. The advantages are: ability to use standard modules; greater ease of check-out; and less stringent requirements on circuit design.

REVIEW: This paper presents some specific examples of part and circuit redundancy techniques as applied to some typical digital circuits. The mathematical analysis, based on elementary probability, is given in considerable detail. The advantages and disadvantages of each application are mentioned. The disadvantage of difficulty in design in part redundancy could well be a major factor in deciding whether to select this technique for a particular circuit application.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improving reliability through packaging

AUTHORS: D. F. Christensen and M. E. Nelson, Dow Corning Corporation, Midland, Michigan

SOURCE: Electronic Industries, vol. 20, July, 1961, pp. 106-109

PURPOSE: To present complete design information on new materials and techniques for higher reliability packaging.

ABSTRACT: Electronic packaging can assure the new high reliability levels demanded by the military services and industry by protecting the components from:

1. foreign fluids such as moisture and oil
2. external heat (by low thermal conductivity)
3. internal heat (by high thermal conductivity)
4. shock and vibration (by resiliency)
5. electrical effects and corona (by eliminating air)

Some of the troubles with encapsulants are difficulty of repair, opaqueness, and processing difficulties. The designer must weigh these factors when choosing a material. Silicones have the best thermal resistance, their electrical properties are constant over wide temperature and frequency ranges, their resistance to moisture and corona is good and they are usable over a wide temperature range. The RTV (room temperature vulcanizing) silicones are repairable but opaque. Dielectric Gel, which is a soft transparent silicone, is now available. The gel is not self-supporting and can be used only for potting. Self supporting transparent silicone embedding compounds are also available. They are flexible and offer easy repairability since the material bonds well to itself. The silicones have many processing conveniences. A table shows which silicone products to use in various applications.

REVIEW: There is no design information since no quantitative data are given for any properties. The only new materials discussed are some silicone products. The assertion that packaging can assure the high reliability levels needed is somewhat extravagant. A paper such as this would be much more helpful if it did not try to be so general and was much more specific about the two new types of products.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure rate study for the lognormal lifetime model

AUTHOR: Lynn R. Goldthwaite, Bell Telephone Laboratories, Incorporated, Allentown, Pennsylvania

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 208-213, January, 1961

PURPOSE: To study the implications that the lognormal assumption holds for device reliability, and to assess the effects of inferences based on the exponential assumption when the lognormal assumption is in fact applicable.

ABSTRACT: A statistical model implying a nonconstant failure rate has been useful in analyzing the reliability of semiconductor devices. This model is the lognormal distribution which implies that the logarithms of lifetimes are normally distributed. This paper is concerned with the implications of applying analyses based on the constant failure rate assumption if a lognormal distribution is in fact appropriate. Curves showing the characteristics of the lognormal failure rates and a simple graphical method for estimating the lognormal parameters are presented.

A comparison of the exponential and lognormal distributions is made. The implications of using the exponential distribution in situations in which the lognormal is in fact appropriate are considered in terms of specific examples. An example of lognormal failure rate analysis is given.

It is pointed out that the lognormal failure rate model does not contain the constant failure rate model as a special case. Therefore constant failure rate approximations to true lognormal distributions are generally inadequate since they are either too large or too small depending on the percentage of failures in a sample and the shape of the underlying distribution. In the case of lognormal distributions with large median lifetimes, however, the lognormal failure rates frequently change little over considerable lengths of time.

REVIEW: This paper is a useful contribution to the theory of mathematical models in life testing. It calls attention to the lognormal distribution as a possibly suitable model to cover situations in which a nonconstant failure rate is appropriate. Whenever sufficient data exist to make a check possible, attention should be given to determining which of the available models provides the best representation of given data.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How ARGMA estimates weapon trends

AUTHORS: A. Steinberg, E. L. Bombara, and S. M. Jacks, Army Rocket and Guided Missile Agency, Huntsville, Alabama

SOURCE: missiles and rockets, vol. 9, no. 5, July 31, 1961, pp. 31-32

PURPOSE: To describe the technique used by the Army Rocket and Guided Missile Agency (ARGMA) to keep track of progress toward reliability in the development of its weapons systems.

ABSTRACT: This paper describes the way in which the Army Rocket and Guided Missile Agency (ARGMA) uses estimated reliability trends to keep track of how its weapons systems are developing toward their defined objectives. Scorekeeping helps to define problem areas of weak designs in subsystems, out-of-control conditions in manufacture, and human factors contributing to mission failure. It is useful in showing progress within a system, but does not serve to estimate specific system reliability or to compare the reliabilities of systems.

The scorekeeping method is briefly described, together with the basic considerations on which it is based. It includes a weighting system used in estimating system reliability. The use of a moving average in obtaining a trend line and the use of a bar chart in depicting subsystem reliability are illustrated.

REVIEW: This paper is a brief qualitative description of the system reliability scorekeeping method used by ARGMA. For the purpose of many readers it may in fact suffer from being too brief.

One statement in the paper is not entirely clear, and would seem to be in error. The statement is: "Component reliabilities will always be less than subsystem reliabilities, in accordance with the multiplication theorem of probability: $P_{overall} = P_1 \times P_2 \times \ldots P_n$." If $P_{overall}$ refers to the subsystem reliability and the P_i to the component reliabilities (which seems to be implied, but is not clearly stated in the paper), then the statement is incorrect. Since the P's represent probabilities and are therefore less than or equal to one, $P_{overall}$ is necessarily less than or equal to the smallest of the P_i. That is, the statement should read "subsystem reliabilities will always be less than the reliabilities of the components comprising the subsystem."

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The planning of space communication system reliability

AUTHORS: Edwin D. Karmiol, Alexander Sternberg, and John S. Youtcheff, Missile and Space Vehicle Department, General Electric, Philadelphia, Pennsylvania

SOURCE: Presented at the Fifth National Symposium on Global Communications, Chicago, Illinois, May, 1961, General Electric MSVD report, 10 pp.

PURPOSE: To describe the methods used at GE to plan for and analyze the reliability of a communications satellite.

ABSTRACT: As in all complex systems, communication satellite reliability is essential in the attainment of the operational objectives. However, the uniqueness of communication operations in space imposes reliability considerations and requirements which are equally unique. This paper discusses the communication satellite system functional and environmental problems and presents a reliability program which has been developed to assure successful system operation in the space environment. The analytical, temporal, and monetary trade-off parameters are fully explored and integrated to develop the necessary reliability design, test, and evaluation program for adequate system reliability. Reliability requirements and associated confidence estimates, project development schedules, equipment costs, and testing costs are the specific parameters covered in the establishment of an optimum program.

An operational profile is first established, providing a valid indication of the operational stresses that will be encountered by the satellite system in the space environment. Equipment design and test requirements are ascertained based on the operational stress profile. Analytical methods are presented which allow maximum use of all available test data in determining the equipment survival probability over the required operational period. Each of these major program areas is reviewed with the purpose of illustrating how these activities can be planned and integrated in assuring space communication system reliability. (Authors)

REVIEW: This is largely a qualitative paper. The quantitative graphs do not have enough explanation to show exactly how they would be used. An interesting point in the paper is the confidence in component reliability vs. confidence in system reliability. Unfortunately no references or derivations are given for the relationships that are used. The value of a paper such as this would be increased if more detail were presented and the scope reduced if necessary.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effect of circuit design on system reliability

AUTHOR: J. J. Suran, Electronics Laboratory, General Electric Company, Syracuse, New York

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-10, March, 1961, pp. 12-18

PURPOSE: To show that worst case design throws a heavy burden on complex systems and can actually reduce reliability.

ABSTRACT: It is shown that circuit drift failures may be eliminated by worst case design procedures but that a considerable price is paid for this immunity in the form of increased system complexity, increased component stresses and increased power demand. Consideration of the entire problem leads to the conclusion that decreasing the probability of circuit drift failures (by increasing the tolerance margin of the circuit) tends to increase the probability of component catastrophic failures and that consequently an optimum component tolerance design point exists for maximum system reliability. The optimum tolerance margin depends upon the specific system and generally varies inversely with the number of components comprising the system. Thus, to maintain a specified system reliability in the face of increasing system complexity, it is necessary to assume a decreasing component parameter spread (tighter tolerances) and a decreasing component catastrophic failure rate. Both of these requirements may be relaxed if some form of redundancy is introduced to overcome the inevitable occurrence of catastrophic failures. (Author)

REVIEW: The subject of how to design circuits for maximum reliability is an important one and this article emphasizes one aspect of it, namely the difficulties that can be caused by worst case design. All of the problems associated with close tolerance design were not mentioned; for example, an accuracy of 1% in a power supply may well require more components than 10% accuracy would.

The calculation of optimum drift vs. tolerance allowances in interesting and one on which more research can profitably be spent. A minor error involves the probability of failure for zero component tolerances--the probability would be one, rather than some number less than one.

In the demonstration that looser component tolerances require increased energy expenditure, the second law of thermodynamics is invoked. The justification for use of the second law is not obvious and a proof or reference to a proof would be desirable.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Sampling plans based on the Weibull distribution

AUTHORS: Henry P. Goode and John H. K. Kao, Department of Industrial and Engineering Administration, Sibley School of Mechanical Engineering, Cornell University, Ithaca, New York

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 24-40, January, 1961

PURPOSE: To present a proposed set of acceptance-sampling plans for life testing and reliability when the underlying life distribution is of the Weibull form.

ABSTRACT: The underlying life distribution is assumed to be Weibull with mean μ and shape parameter β. The range of values of β selected for the study is 1/3 to 5. The lot or product quality is expressed in terms of mean life μ.

For the plans considered, the acceptance-sampling procedure for life testing is as follows:

1. Select a random sample of n items from the lot.
2. Test items for some preassigned period of t time units.
3. Denote by y the number of failures observed prior to time t.
4. Accept the lot if $y \leq c$, the acceptance number; reject the lot if $y > c$.

The probability of acceptance for a lot P(A) under plans of the above form depends on p', the probability of item life being less than or equal to t. For β known and preassigned t, p' is thus a function of mean item life μ. The operating characteristics of any specified plan depend only on t and μ, and in order to provide tables for general use, the ratio t/μ is used. A set of conversion tables is given to provide the connection between t/μ and p'. With these tables, acceptance-sampling plans of desired form can be designed or evaluated using attribute sampling theories. A procedure using these conversion tables for applying the MIL-STD-105B plans to reliability and life testing applications is included.

Several examples are provided, the first of which illustrates the use of the conversion tables in conjunction with the MIL-STD-105B tables. It also illustrates the importance of considering the shape of the life density. If the underlying distribution is of the Weibull form but the exponential is assumed, the actual operating characteristics of the plan may differ markedly from those comtemplated.

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RELIABILITY ABSTRACTS
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Double and multiple sampling plans provided in MIL-STD-105B can also be used for reliability and life testing applications.

Tables of sampling plans are provided, one table for each of the nine values of β. Each table lists values for the acceptance number, c, and for minimum sample size, n, for a variety of t/μ ratios. Two further examples are given to illustrate the use of these tables.

REVIEW: This paper provides a valuable source of information for the engineer or statistician wishing to design or evaluate acceptance sampling plans for life testing. The plans are based on sampling by attributes and not by variables. In cases for which the cost of the items to be tested is high, it may be desirable to use sampling by variables rather than one of the plans proposed. It must also be emphasized that one needs to know that the form of the distribution is Weibull (includes the exponential as a special case) and the value of the shape parameter, β, because the plans are very sensitive to changes in β.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability test plans

AUTHOR: Martin H. Saltz, Hughes Aircraft Company, Culver City, California

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 12-23, January, 1961

PURPOSE: To provide for those not trained specifically in the field of statistics a basic understanding of the test plan parameters and their effect on cost of testing.

ABSTRACT: Reliability test plans are necessary for determining whether certain hardware satisfies a reliability requirement, for evaluation of engineering changes, and to demonstrate attainment of a reliability objective. Each plan must be designed to meet a particular situation, a matter of economics and scheduling. Several categories of plans are briefly summarized.

The remaining portion of the paper deals with the comparison of test plans with particular emphasis on sequential plans. The parameters of the test plans are defined, namely: (1) acceptable reliability level (ARL), (2) unacceptable reliability level (URL), (3) ratio of acceptable to unacceptable reliability level (λ = ARL/URL), (4) producer's risk (α), and (5) consumer's risk (β). The reliability level may be expressed in terms of mean time between failures, probability of success, per cent or fraction failing, etc. The two criteria used for analysis of test plans are the operating characteristic curve and the cost in terms of the average required hours of test. The effect on cost of the test parameters is stated and shown graphically.

Three examples are given to indicate what can be expected by the engineer when he requests that a test plan be designed for a particular situation. The first example is a sequential test; the second, a fixed sample size test; and the third, a truncated life test.

REVIEW: This paper has value as a summary of the definitions of the parameters of reliability test plans and the effects of the parameters on the costs of the plans expressed in average required hours of test. There are no new contributions to the mathematics of obtaining sampling test plans. As stated in the paper, the equations presented are for the specific problems proposed and should not be used indiscriminately. To illustrate, the solution for example 1 is based or the exponential failure distribution. For other distributions, the formulas are of no value. Furthermore, a typographical error appears on page 15, in the formula for s. Since there may be other errors of this type, it is recommended not to use the mathematical results without carefully checking with other references or with a statistician.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Using circuit design tolerances to optimize reliability and cost

AUTHORS: F. K. Heiden and A. L. Stewart, Vought Electronics, Arlington, Texas

SOURCE: Presented at the SWIRECO 61, Dallas, Texas, April, 1961; Chance Vought Corporation Report No. EL-RIR-3, 7 pp.

PURPOSE: To show how component tolerances are combined to get circuit tolerances.

ABSTRACT: Since rarely will all parts simultaneously have the worst values, worst case design is over-conservative and the parts parameter distributions should be taken into account. A study contract at Vought Electronics showed that many parts have normal distributions, which provides a basis in probability for the usual practice of setting manufacturing tolerances at three standard deviations from the mean. The variance of a function of parts parameters, approximated by linearizing the function, is the weighted sum of the component variances, where the weight is the square of the partial derivative with respect to that component. Several examples are given of the use of the formula. "Consideration of the entire problem leads to the conclusion that an optimum part tolerance design point exists for maximum reliability."

REVIEW: The derivation of the overall variance is not rigorous, because the linear approximation is made without reference to omitting higher order terms and it is not stated that the derivatives are to be evaluated at the mean values of the parameters or that the parameters must be statistically independent. Data exist which show that some part parameters are not normally distributed; and therefore 99.73 per cent of them will not necessarily be included between tolerance limits set at three standard deviations from the mean. A statement about tighter tolerances requiring higher power dissipation and more components is opposite to the conventional viewpoint. The important concepts of drift in mean value and standard deviation are not considered.

The use of distribution functions to calculate component and circuit tolerances probably gives more efficient circuit design than worst case methods, although in many circuits it may be much more complicated to apply. The reader interested in this topic may wish to refer also to the two papers listed below.

REFERENCES: Dreste, Fred E., "Circuit design concepts for high reliability," Research and Development Reliability, American Society for Quality Control, 1961, pp. 172-192 (See Abstract and Review Serial Number 25.)

Nussbaum, E, Irland, E. A., and Young, C. E., "Statistical analysis of logic circuit performance in digital systems, "Proceedings of the IRE, vol. 49, no. 1, pp. 236-244, January, 1961 (See Abstract and Review Serial Number 35.)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Cooling electronic equipment

AUTHOR: A. Donald Hay, Chief Engineer, McLean Engineering Laboratories, Princeton, New Jersey

SOURCE: Electronic Equipment Engineering, vol. 9, no. 8, August, 1961, pp. 18-20

PURPOSE: To show the use of design equations for forced air cooling.

ABSTRACT: Design of an efficient cooling system for electronic equipment requires consideration of such factors as air velocity, pressure differential, filters, and type of blower used. Thermal resistance is due largely to an air film surrounding the hot body, and high speeds are needed to break this film down. Designers must know the amount of dissipated heat to be removed and the temperature rise desired for the coolant. The author assumes Newton's law of cooling and gives film coefficient values for air speeds up to 100 feet per second. A graph for the solution of the equation relating the variables is presented.

The importance of not specifying more differential pressure than necessary is noted. For example, an increase in pressure of one inch of water can more than double the power requirement, but increase the heat transfer rate by less than one quarter of one per cent. For vacuum tube assemblies the required differential pressure is seldom over one eighth inch of water plus the pressure drop across the filter. Relationships are given for approximating the required pressure differential when solid state components on printed card circuits are mounted beside one another. The advantages of locating the filter and blower assembly at the air inlet to the equipment to be cooled are discussed. The characteristics of a good filter are mentioned.

Blower and fan performance is evaluated by a dimensionless ratio called Specific Speed, N_s. The equation is $N_s = NQ^{1/2} (g\Delta H)^{-3/4}$, where N is the rotating speed, Q is the rate of discharge, g is the acceleration of gravity, and ΔH is the pressure head of fluid flowing across the unit. Each type of blower or fan is most efficient in a certain range of N_s. A table shows the ranges for propeller and mixed flow fans, and for squirrel cage and radial wheel blowers; a figure gives the relationship between pressure, impeller diameter, and speed. An illustrative example is given.

REVIEW: Since high temperatures reduce the life of equipment, proper cooling is important for good reliability. This paper will help to introduce the non-specialist to the problems of air cooling of electronic equipment. However, no mention is made of the reliability of the blower under operating conditions. This is most important since a non-operating blower can cause equipment failure. Filters which need replacing can have a similar effect.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some comments on the semantics of quality and reliability

AUTHORS: E. L. Grant and L. F. Bell, Stanford University, Palo Alto, California

SOURCE: Industrial Quality Control, vol. 17, May, 1961, pp. 14-17

PURPOSE: To show the similarities and differences between quality and reliability.

ABSTRACT: The popular meaning (and dictionary definition) of "quality" is "degree of excellence." There are four technical uses of the word:

1. degree of excellence of the design objective, or "quality of design."
2. effectiveness of design specifications toward meeting design goals or "quality of specifications."
3. conformance of product to specifications, or "quality of conformance."
4. "quality of," meaning "property of," which is a meaning distinct from the above three.

The technical and popular meanings of "reliability" are not as similar as are the technical and popular meanings of "quality." Again, the dictionary reflects the popular usage--if it is reliable, it is trustworthy; there is no factor of time as in technical definitions. Technical "reliability" seems to be just one facet of popular "quality." The tendency on the part of reliability people to consider themselves outside of quality control is dubious. It seems that much of their effort is devoted to quality of design and specifications. It is interesting to note that, historically and in general, neither designers nor quality control people felt that quality control groups should advise design groups.

The jurisdictional disputes between reliability and quality control people are unfortunate, especially so if they should spread to new areas such as maintainability groups. Whatever words are used to describe the degree of excellence of a product, they will inevitably be used differently at times.

REVIEW: This is an interesting and provocative article on the philosophy of reliability and quality control. The points discussed have undoubtedly puzzled many newcomers to the field. Interestingly enough, one of the main objectives of reliability research today is to find those qualities in production which are directly correlated with life, so that less "reliability" testing and more "quality" testing can be done.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A Markovian model for predicting the reliability of an electronic circuit from data on component drift and failure

AUTHORS: D. M. Brender and M. Tainiter, International Business Machines Corporation, Watson Scientific Computing Laboratory, New York, New York

SOURCE: Research Report RW-32, 36 pp., International Business Machines Corporation, New York, New York, May, 1961

PURPOSE: To present and discuss a mathematical model for the prediction of the reliability of an electronic circuit from life test data.

ABSTRACT: The variations of parameter values of the components of an electronic system are assumed to follow stationary Markov laws, independently. The ranges of these parameter values are "quantized" and thus each parameter is considered to lie in one of a finite number of discrete states. It is assumed that this quantization replaces, for each component, the original continuous-time Markov process by a continuous-time Markov chain. With this assumption it is shown that the system can be considered as lying in one of a set of discrete states and also has the Markov property. Each set of component states defines a state of the system. The reliability of the circuit is evaluated. Reliability is here determined by the distribution of the time to first failure of the system, where failure occurs when the system reaches certain specified states. This includes the case of drift to unacceptable levels, and catastrophic failure. Formulae are derived for the moments of the time to first failure, both unconditional and conditional on a given initial system state. Finally the expressions for the probability of a given system state at any time are given.

REVIEW: The assumption made, that the component parameter values are continuous-state Markov processes, is a very plausible one, and the independence assumption is a logical first assumption to make. What is not clear is that the Markov properties will be retained when the parameter values are grouped into "states," even though these states may contain only an arbitrarily small range of parameter values. That is, when the continuous-state process becomes a chain, the Markov assumptions may no longer be even approximately true. It seems therefore that the basic assumption is that the component parameter values form continuous-time Markov chains, and this would require rather more verification in practice. However, in cases where this assumption is a valid one (and it would be interesting to try to test it on actual data), the mathematical development leads smoothly to useful results. As noted by the authors, the results for the mean and variance of the time to first failure will be most useful, as well as those for the reliability function. It will be interesting to see whether the computational problems mentioned by the authors can be overcome sufficiently to apply this model in practical cases.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Equipment trends for reliable communications

AUTHOR: A. F. Culbertson, Director of Engineering, Lenkurt Electric Company, Incorporated

SOURCE: Signal, vol. 15, no. 12, August, 1961, pp. 65-66

PURPOSE: To discuss some of the considerations involved in the design and production of highly reliable electronic communications equipment.

ABSTRACT: In the Atlantic Missile Range a data transmission system has been in service for over one year. This system includes a total complement of over 2000 transistors and 4000 diodes. During this period there have been only three component failures--two of which were semiconductors: one transistor and one diode.

While it is true that transistorized equipment can be designed to be ultra-reliable, it does not necessarily follow that just because equipment is transistorized it will fall into the high reliability category. A number of other considerations are important.

One consideration faced by the producer of reliable equipment is that of controlling the manufacture of his own critical components. The demands of a commercial components market and the demands of high reliability equipment often are not compatible. The maintenance of a carefully controlled set of electrical standards is essential in meeting the accuracy requirements for reliability in an electronic circuit. Automation of production operations can provide a higher degree of reliability in the end product than that provided by methods subject to human fallibility.

In the design of equipment using redundant circuitry, automatic fallback, etc., it is important not to over-complicate the circuit. Another factor to be taken into account in the design of equipment accessible for repair is that of maintainability. Still another factor is that of heat dissipation, which may not be entirely looked after by the use of solid state components. There is a need for close collaboration between the mechanical engineer and the electronic engineer at every step of the circuit design if high reliability is to be achieved.

REVIEW: The brief discussion provided in this paper points up some very important considerations in the design and production of reliable electronic equipment. It emphasizes the need for deliberate and careful effort, and for the taking into account of many pertinent considerations. In connection with the reference to the automated production of components, it may be of interest to the reader to see also Abstract and Review Serial Number 19.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Safety margins established by combined environmental tests increase Atlas missile component reliability

AUTHOR: C. C. Campbell, Convair (Astronautics) Division, General Dynamics Corporation, San Diego, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-10, March, 1961, pp. 1-6

PURPOSE: To describe testing procedures and techniques used to determine relative component reliability in the Atlas missile.

ABSTRACT: The test program known as "Search for Critical Weaknesses" is used to detect critical component weaknesses through environmental testing. Safety margins are established by testing all components beyond operational requirements and under combined environments. The program is under the control of a group independent of the designers.

So far, 203 component types have been tested. The sample size for each component type selected was determined by its relative importance to the over-all system and by the total numbers of each component used per missile. The samples were selected at random from production stock. Only the most severe environments were used, to reduce test time; usually these were high and low temperature, altitude and vibration. There were three levels of testing: the first was a nominal one at which no failures were expected; the second was the highest level even rarely encountered; the third was still more severe. The results of all tests were statistically analyzed.

Two important factors were found, viz. (1) the equipment should be operating while under test and (2) the combined environments should be applied while it is operating. Several examples are given of unexpected failures that were uncovered in this way. Once a weakness is found, it can be analyzed in more detail by the Reliability Diagnostic Laboratory. Corrective action varies from intensified inspection techniques and improved materials to complete redesign or change in vendors. A definite trend for improvement is toward simplification, and the elimination of as many moving parts as possible.

REVIEW: The examples of failures and the steps taken to improve them are quite interesting. The use of combined environments in testing has been mentioned by others and seems to be very important. The use of a safety margin is quite wise, although it is difficult to put it on a quantitative basis.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The Electronic Component Reliability Center--An evaluation of the first year's operation

AUTHOR: J. R. Funk, Hughes Aircraft Company, Ground Systems Group, Fullerton, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-10, March, 1961, pp. 7-11

PURPOSE: To describe the Electronic Component Reliability Center (ECRC) at the Battelle Memorial Institute.

ABSTRACT: The ECRC is a cooperative program sponsored by a number of companies and administered by the Battelle Memorial Institute. It has two objectives: to evaluate and summarize the pooled electronic component part test data of the member companies, and to conduct research on the development of reliability analysis techniques. So far the data have been restricted to transistors, diodes, capacitors, relays, and resistors. The data are summarized on special forms and include information that is not readily available otherwise. Some of the information is on initial parameter values and the rest is on life tests. Non-parametric analysis is generally used, e.g., minimum, 10%, 50%, 90%, and maximum values might be given. Approximate formulas allow conversion to mean and standard deviation. These data are useful for the selection of transistor types, but should not be used to choose vendors. The ECRC reports also have a discussion on reliable application of the component. An important research phase is to try to find initial parameters that correlate with life times so that long life components can be non-destructively found.

REFERENCE: ECRC Transistor Report, Battelle Memorial Institute, Columbus, Ohio.

REVIEW: In principle, the program seems excellent. Some things are not clear from the paper, but may be so in the references; for example,

1. Do vendors submit the results of their own tests on their own products or are the tests made by a customer?
2. There are two sets of distribution formulae--probably for two different distributions. No mention is made of this.

It is difficult to see why the data might be good for the selection of transistor types, but not good for the selection of vendors. The research work, although not described in detail, seems quite worthwhile. Some of the problems seem to be those of getting any program under way, and undoubtedly they will be overcome. Apparently the results will not be made publicly available, a disadvantage when compared to the IDEP, which distributes information at least to DOD vendors. (See Abstract and Review Serial Number 27.)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Measuring missile reliability in prelaunch environments

AUTHOR: David S. Stoller, Logistics Department, The Rand Corporation, Santa Monica, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-10, March, 1961, pp. 19-25

PURPOSE: To describe some of the problems involved in measuring missile reliability in the prelaunch environment.

ABSTRACT: The prelaunch phase is important because (1) a missile typically is exposed to many different environments before launching; (2) a missile's reliability history in the prelaunch phases is an index of its in-flight reliability; (3) the major cost of a missile system derives from the consequences of its prelaunch behavior. Most reliability measurements have been for in-flight conditions; the prelaunch reliability has been inferred on the basis of other data, such as supply transactions, and is generally not accurate. Several of the important prelaunch operating environments are: turn-on (-off), checkouts, countdowns, operating alert, standby alert, handling, storage, transporting, and periodic maintenance. Monitoring the reliability history of small aggregates, such as pumps, is most important during research, development, and early operation phases but later becomes a burden. When the system is in operation it is important to monitor the large aggregates, such as a ground guidance station, so as to gain knowledge of operational effectiveness. Data on the small items are still important and are obtained as follows:

(1) define standard operating environments for large aggregates,
(2) relate the operating environments of smaller aggregates to the standards of the large aggregates,
(3) monitor only the large aggregates,
(4) synthesize the reliability history of small aggregates from (3),
(5) relate standard and synthesized environments to design environments by bench test.

A missile status log can be a source of information for the above program and can also provide data for other services such as maintenance and supply. The log has five categories:

(1) time reference of event causing entry,
(2) impact of event on weapon-system effectiveness,
(3) consequences of event on operations-maintenance status,
(4) identification of aggregates,
(5) remarks for local use.

REVIEW: This is a reasonable treatment of the problem of prelaunch reliability. Constant failure rate is assumed for each phase of prelaunch life, such as operation, storage, and turn-on, although it is not essential to the rest of the paper.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The effect of the NOL and Battelle data interchange programs on Librascope reliability test efforts

AUTHOR: Leonard G. Rado, Librascope Division, General Precision, Incorporated, Glendale, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-10, March, 1961, pp. 26-28

PURPOSE: To describe two data exchange programs.

ABSTRACT: The NOL Fleet Ballistic Missile Weapons System (FBMWS) Reliability History Survey Program was started several years ago and has grown in size and stature since then. The contractors send the results of their test efforts (usually on components) to NOL at Corona. There they are condensed, put on forms, and distributed to interested testing firms and contractors involved in the program. Searches for tests on a particular component can also be run.

The Battelle program (ECRC) is paid for by the sponsoring member firms (13 at present). Battelle receives and compiles the test reports. They may also prepare a large report using all the tests on a single component. Statistical data are then extracted.

The two systems have basically the same major objectives: to reduce duplicate testing and to show how to run good tests. An important by-product of participation in these programs is the network of cross-relationships which builds up among the personnel involved. The NOL program is being integrated with the IDEP.

REVIEW: This is a brief and interesting account of one company's general experience with two data exchange programs. These data exchange programs are very worthwhile--especially insofar as the results are made public. (See also Abstracts and Reviews Serial Numbers 27 and 54.)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A measure of reliability and information quality in redundant systems

AUTHORS: S. A. Rosenthal, H. Jaffe, and M. D. Katz, Air Armament Division, Sperry Gyroscope Company, Division of Sperry Rand Corporation, Great Neck, Long Island, New York

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-10, March, 1961, pp. 29-37

PURPOSE: To introduce operational worth as a system concept and show how it is used in making trade-offs in the system characteristics.

ABSTRACT: The system worth concept is an essential tool in the synthesis and analysis of complex systems. As described, it enables the system designer to evaluate the incremental benefits attributable to specific system improvements in accuracy, reliability, redundancy, and alternate mode capability. During the early phases of system design, the accuracy and reliability data used in the system worth analysis will be predicted from empirical relationships. Verification of the empirical data can later be made from field data when the system becomes operational.

Although the system worth model was developed for the synthesis of an optimum redundant configuration for the B-58 bombing-navigation system, it has universal application to any system where alternate paths of differing information-handling capability are used. (Authors)

REVIEW: The concept of system worth described in this paper may well be of interest to many engineers concerned with the design of complex electronic equipment. Its adaptation to any specific case will, of course, require careful evaluation of the operational and design factors involved. The reader may be interested in noting that the material in this paper is very similar to that in another paper by the same authors, cited in the reference below.

REFERENCE: "Designing reliability into the B-58 bombing-navigation system," by Mordecai D. Katz, Herbert Jaffe, and Stanley A. Rosenthal, Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 273-282, January, 1961 (See Abstract and Review Serial Number 6.)

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Designing diode-inverter transistor logic circuits

AUTHOR: Richard B. Hurley, Advisory Engineer, IBM Corporation, San Jose, California

SOURCE: Electronic Equipment Engineering, vol. 9, August, 1961, pp. 55-58

PURPOSE: To show how to design diode-inverter transistor logic circuits using worst case design and to caution that this may not be optimum.

ABSTRACT: The discussion is limited to npn transistors, UP voltage logic, common emitter circuits, and ground referenced signals. Within these limits there are UP-NOR (NOR and logical extensions) and UP-NAND (NAND and logical extensions) circuits. Design considerations are similar for all of these. Three common design philosophies are: (1) nominal (with safety factors), (2) statistical, and (3) worst case. Combinations and degrees are possible for all. The example considers Absolute Worst Case (AWC) design and uses the conventional electrical laws for the "on" and "off" calculations. Generally, the results are in the form of inequalities and some judgment is possible. While the minimum transistor gain was 72 in the example, the design has a (very poor) positive fan-out of two. The reasons for the poor result are: (a) voltage and temperature effects were not correlated, (b) high speed was attained by sacrificing gain, and (c) statistical probability was ignored, yet the probability of all parameters being at their worst values at once is very small. Other less severe techniques can be used, such as purchase worst case and statistical design, to modify the circuit. The AWC is a conservative guide.

REVIEW: The AWC design is the main part of the article and some disclaimers are inserted at the end. No distinction is drawn between good design for individual circuit reliability as against over-all system reliability. That is, for complex systems conservative design may require more parts; the system then has a higher probability of catastrophic failure even though the probability of out-of-tolerance failure is lower. Both kinds of failure must be taken into account. A good discussion of pertinent statistical techniques is given in reference (1). Another discussion of worst case design is given in reference (2).

REFERENCES: (1) Nussbaum, E., Irland, E. A., and Young, C. E., "Statistical analysis of logic circuit performance in digital systems," Proceedings of the IRE, vol. 49, no. 1, pp. 236-244, January, 1961 (See Abstract and Review Serial Number 35.)

(2) K. M. Trampel, "Designing NOR circuits for maximum reliability," Electronics, vol. 34, June 2, 1961, pp. 46-48 (See Abstract and Review Serial Number 24.)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure-proof amplifier

AUTHORS: Vincent Babin and Anthony E. Lofting, Lenkurt Electric Company, Incorporated, San Carlos, California

SOURCE: Electronic Equipment Engineering, vol. 9, August, 1961, pp. 37-38

PURPOSE: To describe a transistor amplifier which has redundancy to keep the output constant.

ABSTRACT: The circuit was developed as part of a highly reliable military communications system. This is a dual transistor amplifier which has two identical amplifier units connected so that a failure in either causes no output change. The unit amplifier feedback is by input and output bridges; they control the terminal impedances and the gain response. Special transformers are used in both the input and the output. The main innovation here is a common connection for both feedback paths. This causes the unit with the best properties to assume a greater share of the load. This is a continuous process--operating from the condition of identical amplifiers to that of one failed. The special output transformer has a resistor connected with two of the windings. This resistor absorbs any extra output power due to an unbalance in the two units; the voltage across this resistor is a measure of that unbalance. When one unit has failed, this special resistor has a voltage across it equal to the output voltage. Thus it can be used to monitor the system and a failed unit can be changed immediately.

REVIEW: The circuit described is an interesting one and certainly is a potential contribution to increased reliability. No reliability calculations are shown, and this is a disadvantage for the article. Undoubtedly the more complex transformers are less reliable and the two unit amplifiers take twice the power of one. These factors, along with others, may reduce the effectiveness of the redundancy.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A decentralized team approach to quality and reliability

AUTHORS: T. E. Smith and A. W. Wortham, Semiconductor-Components Division, Texas Instruments Incorporated, Dallas, Texas

SOURCE: Industrial Quality Control, vol. 17, January, 1961, pp. 16-19

PURPOSE: To describe the quality and reliability organization of the Semiconductor-Products division of Texas Instruments Incorporated.

ABSTRACT: The authors feel that quality and reliability are too closely allied to be separated; that engineering, manufacturing, and quality assurance have joint responsibilities in this area; and that maximum success can be achieved only through teamwork of these functions.

The organization of the Semiconductor-Components Division of Texas Instruments Incorporated is briefly described. Each product department has its own quality control and reliability assurance groups, specializing in the products manufactured by the specific department. The inspection of incoming material is handled in common for all departments. A three-stage development for new products is described.

The objectives of quality assurance engineering in establishing effective process control are discussed, together with their role in meeting present-day reliability requirements. In this area, and also in research and development, statistical methods are found to be an invaluable tool. The function of an operations research group as a branch of quality assurance is described. The authors feel that the present quality/reliability organization is the most effective one possible for the present requirements of their division, but should these requirements change, any necessary modifications will be made.

REVIEW: This is an effective description of the approach taken by one company to the organization of their quality/reliability function. If good trained people are available, there is much to be said for the decentralized approach to this problem. The paper has much food for thought, especially for those concerned with organization and management.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Are statistical life-testing procedures robust?

AUTHOR: --

SOURCE: Industrial Quality Control, vol. 17, February, 1961, pp. 5-6

PURPOSE: To review the referenced papers.

ABSTRACT: (Covered by REVIEW, below.)

REVIEW: This is a review of work done at the National Bureau of Standards, Washington, D. C. on the evaluation of the robustness of acceptance sampling procedures used in life testing experiments. The work is described in the two references listed below.

REFERENCES: "The robustness of life testing procedures derived from the exponential distribution," by M. Zelen and Mary C. Dannemiller, Technometrics, vol. 3, pp. 29-49, February, 1961 (See Abstract and Review Serial Number 17.)

"Mathematical research on reliability prediction," NBS Tech. News Bulletin 44, 24(1960)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The management of reliability programs

AUTHOR: Frank H. Squires, Frank H. Squires & Associates, Management and Quality Control Consultants, Los Angeles, California

SOURCE: Industrial Quality Control, vol. 17, April, 1961, pp. 5-8

PURPOSE: To discuss the qualifications for a manager of a reliability program.

ABSTRACT: Quantitative reliability is a statistical concept, especially in machines with no operators, such as guided missiles. A reliability program, like anything else, will succeed only if managed correctly. The manager must have (1) technical familiarity with the engineering and statistics, (2) administrative experience, and (3) compatibility with the requirements of the position. The latter requires that he be more concerned with reliability measurement than with product development or production problems. His disposition should be such that he can be happy within these limitations. He must both manage his subordinates and coordinate his work with other departments.

An effective reliability program will begin with a mathematical model and will end with a prediction. The goal will be measured statistically and the major steps in the program will be valid only as they fit into the statistical plan.

REVIEW: This is an interesting article intended for management rather than to provide technical information for engineers. Those interested or involved in reliability management would do well to read the paper, if only for academic reasons. The emphasis on quantitative reliability as a statistical concept is a worthwhile feature. The view that consumer and industrial product reliability need not be very high is debatable--many feel that it ought to be much higher than it is. Admittedly the demand for reliability in missiles and space vehicles is urgent, but the manufacturer of consumer goods who neglects this aspect can readily lose out to competitors.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability procurement

AUTHOR: M. R. Seldon, Vought Astronautics Division, Chance Vought Aircraft, Inc., Dallas, Texas

SOURCE: Industrial Quality Control, vol. 17, April, 1961, pp. 8-9

PURPOSE: To show what specifications and information management must have to effectively control reliability.

ABSTRACT: The major problem with practical reliability achievement is effective management. Contracts, procurement documents and specifications are management tools and must be clear to managers. The Aircraft and Missile Division of ASQC prepared a list of reliability specifications used by the military. Corporate management cannot understand them.

A listing is made of desirable and of mandatory specification requirements. This is followed by a listing of the unacceptable and of the undesirable characteristics of present specifications. This situation clearly must be corrected.

REVIEW: This is a rather strongly written discussion for managers; it does not provide technical information for engineering design. While some of the emphasis is debatable, certainly the main points are worthwhile and the effort on improvement of reliability specifications should continue.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Total quality control through reliability

AUTHOR: Frank M. Gryna, Jr., The Martin Company, Baltimore, Maryland

SOURCE: Industrial Quality Control, vol. 17, April, 1961, pp. 10-12

PURPOSE: To describe the Martin reliability management program.

ABSTRACT: This article describes how Martin-Baltimore has expanded its quality control concept into a comprehensive reliability program. The program is based on nine policies, such as "Reliability is an element of product performance distinct from capability..." and "A realiability program must start in the proposal phase... and continue throughout design and development,... field evaluation, and service use." On each program the Program Manager is responsible for both capability and reliability. A document, MRM (Martin Reliability Management), has been drawn up and explicitly lists the many necessary steps to assure reliability. There are eight main points, namely (1) define the reliability objective in specific terms, (2) define each of the steps to be taken in the program, (3) establish the responsibility for each step, (4) list the other organizational units concerned with each step, (5) provide adequate funds for each step, (6) prepare written procedures detailing how each step in the program will be performed, (7) establish time schedules for the preparation of the written procedures and completion of the step, and (8) the "control" aspect of reliability (checking to make sure things are done).

REVIEW: As a description of the reliability program of one company, this article may be of interest to those concerned with the organization and/or management of potentially-similar programs in other companies. Naturally the specific details of any such program must be worked out to meet the requirements of the situation in which it is to be applied.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Presentation of reliability information

AUTHOR: Samuel S. Shapiro, General Electric Company, Schenectady, New York

SOURCE: Industrial Quality Control, vol. 17, April, 1961, pp. 13-15

PURPOSE: To describe a system for concisely presenting reliability information.

ABSTRACT: The Master Control System for quality control (reference cited below) solved the problem of concisely presenting quality control information. This system has been adapted for the presentation of reliability information. The adapted Master Control System consists of the following basic parts: the Master Control Sheets, the principle of pyramiding, a criterion for determining significant changes in reliability, and a summary block diagram. The basic parts are described and illustrated. In the pyramiding system, charts are produced for each subassembly, then charts for each assembly, and then a chart for the whole system. A manager may look only at the latter, a designer only at one of the first. The charts provide the means for showing the required reliability, the present reliability, any significant changes, the test times and the numbers of failures.

REFERENCE: <u>Industrial Quality Control</u>, vol. 7, October, 1955, p. 17

REVIEW: This paper will be of interest to those facing the problem of presenting large quantities of reliability information to people at various levels in design and development work. The description given is clear and adequate for the purpose of the paper. The potential user of the ideas must, of course, be prepared to make whatever adaptations may be required in his own situation.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Management policies for assigning departmental reliability responsibilities

AUTHOR: Leslie W. Ball, Aero-space Division, Boeing Airplane Company

SOURCE: Industrial Quality Control, vol. 17, April, 1961, pp. 16-19

PURPOSE: To discuss some of the problems with which reliability management policy must deal and to make a plea for "management methods research."

ABSTRACT: This year, 1961, the most urgent aspect of reliability engineering is the need for management methods research and for implementation of these methods as they are developed. Enough work has been done for the reliability engineering profession to offer to management a clear path for constructive action. General managers can fulfill their own responsibilities and provide effective delegation to the next organizational level by issuing a General Reliability Policy Statement covering Purpose, Organization, Practices, Personnel and Audit and by whole-heartedly supporting the implementation of this policy statement after it has been issued. (Author)

REVIEW: Those concerned with reliability management should find this paper helpful.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability: Why is it needed?

AUTHOR: Richard M. Jacobs, Sylvania Electronic Systems Division, Waltham, Massachusetts

SOURCE: Industrial Quality Control, vol. 17, May, 1961, pp. 26-29

PURPOSE: To show why reliability engineers are needed.

ABSTRACT: This article is presented for those companies contemplating the use of a reliability specialist. Reliability engineering is defined as the integration, interpretation, coordination, and motivation needed to increase the useful life of economically produced products. The basic reasons why industry needs reliability engineering are given (together with some discussion) as follows: customers (especially the military services) have reliability requirements and desire assurance that these will be met; competitors have reliability specialists; customers expect someone other than a salesman to hear their complaints, and to confer with them on matters such as design; the reliability engineer serves to integrate information from various specialties ranging from statistical techniques to human problems, and coordinates a wide class of efforts. A chart is used to give an analysis of reliability engineering work in terms of percentages of time on various tasks.

The advent of reliability consciousness has brought with it many changes in procurement methods, manufacturing techniques, and acceptance procedures. There is a greater awareness of the need for adequate specifications. Test procedures are being spelled out more carefully, and quality control personnel are becoming concerned with life requirements. There are trends toward automated production.

REVIEW: This article presents an idealized picture of what a good reliability engineering group could do for a company. It gives the interested reader some things to think about, but answers no specific questions, either technical or managerial. For instance, in staffing a group to do the work the author describes, what criteria should one use in deciding upon a suitable breakdown of talent and training? Certainly no single "reliability specialist" can perform adequately all of the tasks listed by the author.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Life test--some practical considerations

AUTHORS: H. J. Davis, Raytheon Company and B. P. Goldsmith, Northeastern University

SOURCE: Industrial Quality Control, vol. 17, June, 1961, pp. 11-16

PURPOSE: To review current life testing practices in the electronics industry and to propose a new life test sampling plan.

ABSTRACT: Life tests may have one or more of these purposes: exploration of product characteristics, lot-by-lot product acceptance, qualification of a design and/or a process, qualification of a manufacturer, and continuing surveillance of the last two. The conditions under which a life test is run are important. Some methods are: functional, simulated functional or accelerated functional tests under in-use conditions, and environmental profiles. Field tests--while the final criteria--are very difficult to run or to evaluate. Each method has its good and bad points and, of course, costs must be taken into account. The actual test conditions may not be the nominal test conditions because of power failures, inadequate supervision, etc. Sampling is also a problem--especially the determination of what population should be sampled; for example, a product before inspection may be different from one that has been stored for a while. The interpretation and use of life test results requires mature judgment.

Descriptions of representative current specifications are given. A new plan is proposed, having been developed to meet the needs for high reliability electron tubes. An important part of the proposal is a continuing log of test results and a plot of the total number of failures in the last four samples. The amount of sampling required depends on previous performance, but is entirely independent of production quantities. It puts a constant bound on the confidence level associated with the current estimate of the failure rate. The proposal is not limited to any arbitrarily chosen failure distribution. Failure rates and testing schedules may be based on the normal, Weibull, or exponential distributions without making any changes in routine instructions. The plan may be easily adjusted to meet the demands of a variety of situations.

REVIEW: Those concerned with the life testing of components in the electronics industry will find this paper to be of interest, and probably of considerable help. The review of objectives and of test methods is clearly and concisely presented. Certain worthwhile cautions are given, particularly with respect to sampling and the interpretation of results.

The proposed new life test sampling plan appears from the description given to have very desirable properties, although from the information given one cannot verify this. Unfortunately for those who may wish

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to apply the plan, the paper does not give sufficient detail, nor is a pertinent reference given in this connection. Perhaps the authors would be willing to supply such a reference to interested persons.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability and statistical control

AUTHOR: William B. Rice, Aerojet-General Corporation, Azusa, California

SOURCE: Industrial Quality Control, vol. 18, August, 1961, pp. 10-11

PURPOSE: To emphasize the underlying philosophy of statistical control.

ABSTRACT: A system of causes (O) generates populations of characteristics (C_i) which are estimated from sample observations (X_{ij}). We can know about the system of causes or the resulting populations of characteristics only by inference from measurements of the samples. If action is proposed, on the basis of the inferences, it is inferred that the future can be predicted from the past. The inferences from X to C to O do not involve time and are well covered by probability theory. The concept of statistical control is introduced to allow predictability--the time factor. If the system of causes is in control, then the system does not change with time and neither do the C. The X can then be used to estimate C, regardless of when they are taken. From experience is derived the axiom "An operation that is in a state of statistical control tends to remain in that state as long as it is functioning under essentially the same conditions." Some conditions are not measurable, but another axiom (also from experience) states that if the measurable C are in control, then so are the non-measurable C. A manufacturing system must be in control if statistical procedures are to be properly applied and the results are to be predictably successful." The words "predictably successful" and "reliable" are synonymous. In this way the risk of failure can be calculated and weighed against the cost of failure in order to determine the most desirable degree of reliability that should be aimed at.

REVIEW: The reliability referred to here is not "the probability of successful performance," but is rather "predictability" in the probability sense. However, the author attempts to explain the basic philosophical concepts underlying statistical control, which should apply quite directly to reliability testing. Unfortunately the exposition is not very clear. The first axiom is in effect a definition of "essentially the same conditions." The second axiom would infer, for example, that if the length of a part does not change, its surface finish does not. The conclusion seems rather doubtful. The attempt to define randomness in terms of statistical control seems rather incongruous. The problem of time variations is not clearly brought out, despite the discussion. The two statements (1) "If the system of causes is in statistical control, it does not change with time," and (2) "If the operation (system of causes) is not in statistical control, the behavior of its characteristics cannot be predicted with predetermined probabilities," do not seem appropriate since a time varying, predictable system can be

envisioned. If the cause system is allowed to have manifestations which are known variations with time, this fact is not made clear. If not, the article would seem unduly restricted and logically inconsistent.

In summary, the basic motivation behind this paper is good, and a clearly presented discussion of these philosophical concepts could serve a useful purpose. While the paper fails to do this as well as it might, it does serve to prompt some thought on these matters, which is in itself worthwhile.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Circuit considerations relating to microelectronics

AUTHOR: J. J. Suran, Electronics Laboratory, General Electric Company, Syracuse, New York

SOURCE: Proceedings of the IRE, vol. 49, pp. 420-426, February, 1961

PURPOSE: To discuss certain problems associated with microcircuitry, with particular emphasis on the problem of power dissipation.

ABSTRACT: Microelectronics, it is said, will reduce size, weight, and cost and will improve reliability, power utilization, and functional capabilities per unit volume of electronic equipment. Some of the means for this are thin films, reduction of solder connections, increased use of redundancy, and mechanized production. But there are problems: power requirements and heat dissipation, microfabrication compatibility, circuit adjustability, cost, and reliability. Microfabrication compatibility refers to the fact that if some components, e.g. input/output devices, are not reduced in size, there is no point in trying to reduce further the size of the rest of the system, once it is relatively small. If microcircuits will need adjusting, the physical accomplishment of this will present a problem when the components are densely packed.

The power and heat problems encountered in microsystems have recently been recognized. Transistors in such systems are frequently operated at thousands of times their minimum power levels. This is because low-power circuits do not have the high frequency capability which is required. Two design examples are given to illustrate this point. In addition, low power circuits are more susceptible to noise and component variations.

All components exhibit some spread in values around their nominal ratings. Allowing greater component tolerances in a circuit design is synonymous to allowing a greater degree of randomness in the selection of circuit components. This may be thought of as equivalent to an increase of entropy in the circuit. Since the circuit designer cannot permit the greater degree of component randomness to be reflected in the performance of the circuit, it is apparent that some measure of increased energy expenditure must be expected (according to the second law of thermodynamics). Two illustrations of this principle are given.

Circuit power dissipation may be related to packing density, viz., the number of components per unit volume, by solving standard heat-flow equations pertaining to any given structural configuration. If heat is generated inside a volume, the temperature of the components is determined by the conductivity to some heat sink. For example, a one-inch germanium cube surrounded by an infinite sink might have

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150,000 components in it, whereas if the package is cooled by natural convection, this is reduced to 90 components. The use of cooling fins or fans results in an effective decrease in packing density.

In view of these problems, the whole design philosophy will have to be changed if microelectronics is to realize its full potential. It can be predicted that the success of microelectronics will be predicated upon the design of microminiature systems rather than upon the microminiaturization of conventional system designs.

REVIEW: The problems discussed here are fundamental to the future of microelectronics. Unfortunately, examples rather than proofs have been given of the two points (1) higher speeds require more power and (2) allowing greater component tolerances leads to a greater power requirement. The argument given for the second is not a rigorous proof. Both points, for a given state of the art, seem intuitively to be valid. An effort to find as general a proof as possible would be worthwhile. The section on tolerances and entropy is very similar to that in the reference below.

REFERENCE: J. J. Suran, "Effect of circuit design on system reliability," IRE Transactions on Reliability and Quality Control, vol. RQC-10, March, 1961, pp. 12-18 (See Abstract and Review Serial Number 45.)

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Availability--A new approach to the measurement of system reliability

AUTHORS: Morton Barov, Salvatore S. Calabro, and Victor Selman, International Electric Corporation, Paramus, New Jersey

SOURCE: Presented at the Fifth National Symposium on Global Communications, Chicago, Illinois, May, 1961, International Electric Corporation report, 10 pp.

PURPOSE: To present a new measure of availability applicable to complex communications systems.

ABSTRACT: The present definitions of reliability have certain shortcomings when applied to complex, continuously operated communications systems. For the most part, the standard equations do not consider either the continuous operation requirements for communications systems or the fact that these systems are repairable. The present measure of Availability, Up-Time Ratio, is described, and it is shown that it does not provide a full measure of Availability as does the new formulation covered in this paper.

This formulation provides the user with a statement of the probabilistic measure of success analogous to the reliability equation. Of major importance to this new expression is the conception of a Maintenance Time Constraint. This is defined as the maximum time an element may be inoperative without degrading the system below the specified level.

In a given mission, the new availability equation is a function of the repair rate, the failure rate and the Maintenance Time Constraint. The use of this equation is demonstrated for a complex system which uses redundancy as a basic design consideration. Techniques are shown for computing the equivalent failure rate for a repairable n-plexed system and its equivalent repair rate. (Authors)

REVIEW: The idea of an availability equation as a measure of capability is interesting, and may well be of considerable practical importance when related to complex ground systems. However, the paper suffers from a lack of detail on certain points. One of these is an assumption that repair times follow an exponential distribution. The reader will undoubtedly wonder about the rationale for this, and/or the extent to which it is supported by empirical evidence. No derivation of the availability equation is given, although a reference is cited. Neither a derivation nor a reference is given for the generalization of the equivalent failure rate for a redundant system. The same is true for the equivalent maintenance action rate. No details of applications are given. Thus, while the idea discussed is potentially important, the reader interested in using it will require more detail than the paper provides.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Birth, life, and death in microelectronic systems

AUTHORS: B. Widrow, W. H. Pierce, and J. B. Angell, Stanford University, Stanford, California

SOURCE: IRE Transactions on Military Electronics, vol. MIL-5, pp. 191-201, July, 1961

PURPOSE: To discuss an adaptive vote-taker.

ABSTRACT: In order to exploit the technological promises of microelectronics, electronic system techniques must be developed so that defective portions of a system can be tolerated without system malfunction. Such defects might be introduced during manufacture (at birth), or cause errors during operation (life). The number of permanent failures which could be endured by a system before it fails completely will determine its lifetime (death).

In this paper, an adaptive vote-taker is proposed which compares the outputs of paralleled (redundant) system parts in a binary system and determines the most probable answer based on past performance of the separate parts. Initially, the vote-taker assigns equal significance to each redundant part, and (in a binary system) requires that a simple majority of the parts be correct. With experience, the vote-taker continually reduces the weight (significance) of the outputs from those parts that make mistakes, thereby gradually eliminating the defective parts. Thus the vote-takers (which also may be paralleled if they are unreliable) act as automatic repairmen which delete defective parts of a system. System dependability and life expectancy can be made to exceed the dependability and average life expectancy of the component parts.

The heart of an adaptive vote-taker is an element providing variable gain with memory. A variable resistor with memory (memistor), which uses electrochemical deposition or removal of copper to achieve the variable memory, has been successfully applied to this function. (Authors)

REVIEW: An adaptive vote-taker as described here is an interesting concept and is discussed quite well. The paper treats both the mathematical and physical aspects of the problem. Ideas of this sort may well provide the basis for the extremely high reliabilities that military and industrial (and consumer) equipment should have. An implicit assumption in all papers on redundancy is that some parts have lives many times the mean life. The exponential distribution, on which most calculations are based, fulfills this criterion. Obviously, the improvement due to redundancy may be much less if there is a strong wear-out factor in the life.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Use of passive redundancy in electronic systems

AUTHOR: J. J. Suran, Electronics Laboratory, General Electric Company, Syracuse, New York

SOURCE: IRE Transactions on Military Electronics, vol. MIL-5, pp. 202-208, July, 1961

PURPOSE: To discuss some of the problems and benefits of using passive redundancy.

ABSTRACT: Redundancy is now used on a system level in electronic equipment; for example, airplanes carry spare communications equipment. Redundancy can be classed as active if switching elements are involved and passive if they are not. The redundancy may be applied at any circuit level, but this paper is limited to passive redundancy at component and circuit levels. Moore and Shannon (reference cited below) have analyzed relay contact redundancy and some of the highlights are presented here. It can be proved that by using series, parallel and composite iterations, the reliability of a given switching operation can be improved by any desired amount.

Another approach is to use majority logic. Three is the smallest number that can be used; to permit improvement, the single failure probability must be less than 1/2, assuming a perfect decision element. If the decision elements are not perfect, redundancy may be used for them, but even so, the reliability may be seriously impaired. Semiconductor circuits do not follow the same rules as relays because their input/output functions are different. In some cases, the best approach may be to use redundancy only in the weak part of the circuit. In a dc - dc converter, the transistors might be duplicated, but not the transformer. Each problem must be thoroughly investigated in order to use optimum redundancy. Interconnections can be improved by redundant joints. This is more practical in microelectronic circuits than in conventional ones.

REFERENCE: Moore, E. F. and Shannon, C. E., "Reliable circuits using less reliable relays," Journal of the Franklin Institute, vol. 262, September-October, 1956.

REVIEW: This is a summary review article. Most of the information has appeared several times elsewhere and the specialist will find nothing new here.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Power dissipation in microelectronic transmission circuits

AUTHOR: James D. Meindl, U. S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey

SOURCE: IRE Transactions on Military Electronics, vol. MIL-5, pp. 209-216, July, 1961

PURPOSE: To derive design equations which provide optimum performance for small-signal amplifiers.

ABSTRACT: The interrelationship of power dissipation, gain, stability, terminal impedance values, dynamic range and efficiency is investigated for small-signal amplifiers in the middle range of frequencies. Utilizing a novel circuit-design theory which treats a transistor along with its biasing resistors as a single entity, amplifier designs are derived which combine optimum ac performance and minimum dc power dissipation. The product of ac power gain and dc-to-ac efficiency is found to be a useful figure of merit for microelectronic transmission circuits. (Author)

REVIEW: The title is not very descriptive of the paper; the treatment is limited to midband properties of small-signal amplifiers. The figure of merit (ac-power-gain times dc-to-ac-efficiency) is presented with no discussion although its postulation is the most important part of the paper and the results follow from it after some mathematical manipulation. Other figures of merit could have been chosen and it would be instructive to have this one explained.

The paper has design information for the practicing engineer which he should evaluate.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A thermal design approach for solid-state encapsulated high-density computer circuits

AUTHORS: A. E. Rosenberg, Epsco, Inc., Cambridge, Massachusetts and T. C. Taylor, Raytheon Co., Semiconductor Div., Newton, Massachusetts

SOURCE: IRE Transactions on Military Electronics, vol. MIL-5, pp. 216-226, July, 1961

PURPOSE: To analyze the heat flow in a special encapsulated design.

ABSTRACT: This paper considers the thermal problems associated with the design of high component-density encapsulated circuits, constructed with small solid-state components. The thermal resistance to the dissipation of component-generated heat is shown to consist of that of the encapsulating medium, plus that of the external circuit cooling process. Because the external cooling becomes more difficult as the size of an encapsulated circuit is reduced, a method of constructing such circuits is proposed which minimizes the thermal resistance due to the encapsulating medium. This construction makes a large fraction of the allowable component temperature rise available for use in the external heat dissipation process by providing high thermal conductance paths for the transfer of heat from the surfaces of the components to one surface of the circuit structure. Analytical models are developed for the most important heat transfer processes in the proposed circuit structure. The equations based on these models are arranged in a form suitable for design use, and example designs are presented. (Authors)

The proposed construction method is to embed the components and wiring in a thin (as possible) electrically-insulating board and then to fasten a metal sheet to one side of this board. The metal sheet (probably a copper or aluminum foil, several thousandths of an inch thick) conducts the heat to a sink at one edge. This sink is in contact with the cooling medium. The design examples show that the problem of removing heat from small components can be very difficult.

REVIEW: This is an interesting design article and the problem of thermal conduction that it treats is critical for high component-density circuits. This approach may not turn out to be the best, but it is a step in the right direction. More of these good ideas are needed until the problem is brought down to manageable size. This paper will be of assistance to those engaged in design work.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A second progress report on TV-receiver reliability

AUTHOR: E. H. Boden, Advanced Applications Engineer, Sylvania Electric Products Inc., Emporium, Pennsylvania

SOURCE: 6 pp., presented at the Chicago Spring Conference on Broadcast and Television Receivers, Des Plaines, Illinois, June, 1961; A technical publication of Sylvania Electronic Tubes, Receiving Tube Operations, General Engineering Department, Emporium, Pennsylvania, 6/61.

PURPOSE: To present some results of a continuing study of tube reliability in various makes and models of television receivers.

ABSTRACT: A life test program was put into effect in 1954 in which various makes and models of television receivers were operated under accelerated conditions, which were established during a prior study program. The tests consisted of operating ten receivers at 130 Volts AC, on 50 minutes, off 10 minutes of each hour for 1500 hours. Periodically, some receivers were operated under the same conditions as the accelerated group except at 117 Volts AC. Information derived from a comparison of the failure rates of the two groups provided an acceleration factor.

As of the date of the report, 21,660 Sylvania tubes and 7300 tubes of other manufacturers had been tested in a total of 1865 television receivers. A consistent improvement in tube quality was evidenced by the comparison of a 7.7% tube failure rate in 1954-1955 with a 3.6% failure rate in 1959-1960. These failure rates were observed on tubes operating at the 130 Volts AC condition.

Tube failures have been classified in three ways: by type, by circuit application, and by cause. Various comparisons have been made with the aid of the available data. From the test program the following conclusions have been drawn: (1) tube failures continue to decrease, (2) set survival has increased, (3) differences in set survival between set manufacturers continue to be observed, and (4) the percent tube types experiencing no failures in 1500 hours at 130 Volts AC continues to increase by significant amounts.

REVIEW: The results of this project should be of interest to those directly concerned with the design of television receivers, to receiving tube manufacturers, as well as to those making use of such tubes in various applications. The experience with accelerated life testing may well be helpful to anyone concerned with similar testing. Presumably the exact testing procedures and the criteria for determining tube failures are available. In a private communication, the author has indicated that he expects to publish an up-dated version of this report in the Sylvania Engineering Information Service sometime in November, 1961.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Peltier cooling of hotspots

AUTHOR: Donald S. Gage, Northwestern University, Evanston, Illinois

SOURCE: 5 pp., presented at N.E.C., Chicago, Illinois, 1960, Abstracted in Electromechanical Design, vol. 5, August, 1961, pp. 32-33

PURPOSE: To show that the requirements of Peltier cooling are different for moving heat to a lower temperature than they are for moving it to a higher one.

ABSTRACT: Compact electronic equipment has heat sources that must be compensated by a cooling system. In conventional refrigeration, the thermoelectric properties cause heat to flow against the temperature gradient (from cold to hot). Thus the materials should have low thermal conductivity. When cooling hotspots, however, the thermoelectric effect aids the thermal conductivity. This is shown by the equation below. The theory of thermoelectric cooling shows that the figure of merit of a material (usual application) is $\alpha^2/\rho k$; for hotspot applications, however, substances with a poor figure of merit may perform well. The equation for heat transfer is

$$Q_{SRC}(\max) = (1/2)T_1^2\, F_h(s/\ell) + K\,(T_1 - T_o),$$

where $Q_{SRC}(\max)$ is the maximum rate of heat removal from junction #1 (by adjusting the electric current),

T_1, T_o are the junction temperatures ($T_1 > T_o$),

$F_h = \alpha^2/\rho$ is the figure-of-merit for hotspot cooling,

α = thermoelectric "power" of the junction,

ρ = sum of the electrical resistivities of both materials,

k = sum of the thermal conductivities of both materials,

K = heat conductance of the two wires (in parallel),

r = total resistance of the two wires (in series), and

s/ℓ = area/length ratio for each material. (The two materials are considered to be in the form of two wires of the same geometry running between the two junctions. Under these conditions $rK = \rho k$.)

The first term is the Peltier cooling, the second is the thermal conductance cooling. The figure of merit F_h is shown in a table for several materials. It is highest for a cobalt-copper vs nickel junction. In an example the heat removed thermoelectrically across zero temperature difference can be handled by the same geometry of copper wire across a 1.45°C difference. Thus thermoelectric cooling using reported materials

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is inferior to heat conduction in ordinary copper.

REVIEW: This seems to be the first mention in the recent literature that one kind of hotspot cooling is different from refrigeration, as far as thermoelectric methods are concerned. The method of choosing a new figure of merit ($F_h = \alpha^2/\rho$) is not analogous, however, to the method of choosing the conventional one ($z = \alpha^2/\rho k$). Using the author's notation we have

$$Q_{SRC} = \alpha T_1 I + K(T_1 - T_o) - (1/2)I^2 r,$$

and $$W = I^2 r - (T_1 - T_o)\alpha I,$$

where I is the exciting current and W is the energy supplied to the system. (The Thomson effect is ignored in the derivations of the author and in the review--it is generally considered to be small.) Note that both of these equations are correct regardless of the sign of $T_1 - T_o$. Let the coefficient of performance (Q_{SRC}/W) be COP and let $I = \alpha J/r$ where J is a new independent variable.

Then $$COP = \frac{T_1 J + (1/z)(T_1 - T_o) - (1/2)J^2}{J(J - T_1 + T_o)}.$$

Thus for a given set of temperatures, COP is a function of J and z, and z is the only way in which the material parameters (α, ρ, k) enter the expression for COP. For COP > 0 (the only interesting case) z should be large if $T_1 < T_o$ ("uphill" cooling) and z should be small if $T_1 > T_o$ ("downhill" cooling). The condition for maximum heat transfer ($J = T_1$) is the same in either case and z should still be large or small as above.

Note that if Q_{SRC} is not divided by W, the combining of all material parameters is not possible and there is no single figure of merit.

Let $q = Q_{SRC}(\max)\ (\ell/s) = (1/2)(\alpha^2/\rho)T_1^2 + k\ (T_1 - T_o)$.

In the practical cases, all that can be said is that α^2/ρ should be large regardless of the heat flow direction and that k should be large for "downhill" cooling and small for "uphill" cooling. The effectiveness of any material can be judged only by calculating q for each case. As the author points out, q can perhaps be made the highest by using material with $\alpha = 0$ and k very large for "downhill" cooling. It should also be pointed out that some hotspot cooling uses "uphill" or conventional refrigeration.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The application of thermoelectric spot cooling to electronic equipment

AUTHOR: W. R. Stubstad, Collins Radio Company, Cedar Rapids, Iowa

SOURCE: 1961 IRE International Convention Record, Part 6, New York; New York, pp. 38-46, March, 1961

PURPOSE: To describe the performance of a hot-spot cooler and to show how these coolers can be used to improve the cooling of equipment.

ABSTRACT: Recent developments in the construction of thermoelectric coolers have resulted in improved coolers suitable for use in electronic equipment. The continual effort to improve the techniques of cooling electronic equipment led to the investigation of thermoelectric spot cooling. Spot cooling pertains to the cooling of temperature-limiting component parts located within local areas of an electronic equipment. The investigation consisted of the evaluation and application of nine spot coolers constructed to specifications determined by an analysis.

Thermal evaluation of the nine spot coolers showed that each spot cooler either met or exceeded the design requirement of pumping 5 watts over a 30°C temperature difference. The coefficient of performance exceeded 0.5 for each of the spot coolers operated under the design condition. In addition to the satisfactory thermal performance, a spot cooler passed the mechanical shock and vibration requirements for satellite equipments used in Project Mercury.

The information on spot cooler thermal performance was employed in an analytical application of spot cooling to a free-convection and radiation cooled equipment and a forced-convection cooled equipment. The results indicate that free-convection and radiation cooled equipment can be operated in higher temperature environments with spot cooling; moreover, the cooling requirements for forced-convection cooled equipment can be reduced. (Author)

The appendix is a derivation of the first order equations for the performance of a cooler.

REVIEW: The details regarding the performance of these coolers will be of interest to those engaged in cooler design, while the discussion of equipment cooling may be of help to circuit and system design engineers. No figures are given on the life of the devices, although presumably they are quite rugged. This is important, since if the cooler fails, the uncooled part is almost certain to fail also.

One cooling application, not mentioned here, is the reduction of hot spot temperatures, but not below ambient. The requirements for this are different and present thermoelements may not perform as well as plain heat conductive elements. (See Abstract and Review Serial Number 77.)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability trade-off analysis

AUTHORS: Alexander Sternberg and John S. Youtcheff, General Electric Company, Missile and Space Vehicle Department, Philadelphia, Pennsylvania

SOURCE: 1961 IRE International Convention Record, Part 6, New York, New York, pp. 85-108, March, 1961

PURPOSE: To present a technique which permits optimum test planning for reliability demonstration.

ABSTRACT: Trade-off analysis can be used to determine the test program necessary to demonstrate specified equipment reliability objectives. The factors to be taken into account are costs, time, available sample sizes, and the system reliability which can be demonstrated for various equipment test levels. This paper presents procedures which can be used in determining an optimum test program.

Reliability trade-off considerations encompass three areas, viz. analytical techniques, testing-time, and testing and equipment costs. The roles of these are briefly discussed, and illustrated with graphs. It is shown how, by taking analytical, time, and cost parameters into account, testing can be optimized for a specific program. The procedure consists of determining a set of curves on the basis of the relevant parameters and reviewing these to select the most desirable program to meet the limitations imposed by costs, time, samples available, and reliability goals.

Appendix A consists of a description and illustrations of the analytical technique used in obtaining confidence interval estimates for the failure rates (and hence the reliability) of components and systems. Further illustrations are found in tables in Appendix B. Appendix C consists of tables giving equipment reliability at selected confidence levels (50%, 80%, 90%, and 95%) in terms of numbers of failures and amount of test time relative to operational time.

REVIEW: The engineer concerned with the demonstration of adequate system reliability will find this paper helpful. He will, of course, have to adapt the techniques to meet the objectives and requirements of his own particular system development program. The descriptions of the techniques, supported by sample calculations, seem to be quite adequate. Detail on the theoretical basis for the techniques, if it is desired, can no doubt be found in the four references cited by the authors.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A study for determining an optimum burn-in of fixed glass dielectric capacitors

AUTHOR: Lawrence D. Hines, Corning Glass Works, Bradford, Pennsylvania

SOURCE: 1961 IRE International Convention Record, Part 6, New York, New York, pp. 109-114, March, 1961

PURPOSE: To describe a study for the determination of an optimum burn-in of fixed glass dielectric capacitors, with respect to time, voltage level, and temperature.

ABSTRACT: A typical failure-rate curve for capacitors has a high portion early in time followed by a flat portion (depicting a constant low rate of failure), and finally a hump-shaped wear-out section. It has been found that a pre-conditioning burn-in at some level of stress for some length of time eliminates potential early load life failures. A study was designed to provide information for the determination of an optimum burn-in.

The study was set up in the form of a factorial experiment with four values of capacitance, five different burn-in voltages, and half of the devices being subjected to hi-potting (a high-voltage dielectric test), while the other half were tested for dead shorts only. Spectrum tests (to determine the voltage levels of dielectric breakdown) were conducted at elevated temperatures on the devices after burn-in, and the results were compared to spectra of control specimens obtained before burn-in. Survivors of the various burn-in and spectrum tests were placed on an accelerated life test. Analyses of variance were carried out on the percent survival data from the life test.

It is concluded that burn-in voltages of 1000V, 1500V, and 2000V are equally effective in eliminating potential life test failures. A given level of burn-in voltage will eliminate a certain mode of failure regardless of the rated voltage of the device. A burn-in time of 50 hours was found to be adequate, and it is recommended that burn-in tests be conducted at room temperature. The results of spectrum tests at room temperature correlated quite well with load life tests. It is also concluded that severe hi-potting may cause failures instead of merely eliminating potential failures.

REVIEW: This paper treats an important subject, but is too incomplete to permit a critical appraisal. It is very difficult to read and interpret, except possibly for a person intimately acquainted with the tests and terminology. For example, the word "spectra" is defined only by inference towards the end of the paper. A number of the statements could be made more clearly and more supporting evidence could be given.

The conclusions regarding hi-potting and burn-in voltages do not seem

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to agree since the level of hi-potting (4 times the rated voltage plus 200V) is not very much higher than the burn-in voltages mentioned. It is difficult to accept the idea that absolute voltage level rather than a multiple of the voltage rating is important, unless the 300V units were under-rated.

The statistical design of the tests may have been good, but it is difficult to tell from the description given. The model is not stated, but apparently the design was a factorial in which percent survival was assumed to be a linear function of capacitance value, burn-in voltage, the presence or absence of hi-potting, and their second-and third-order interactions. The paper would have been improved considerably if the author had stated the model (including the underlying assumptions), and had said a few words about why it was adopted. That is to say, he should have given a justification for his design. Similarly, some justification should have been given for the use of the third-order interaction as the error term in the analysis of variance. Incidentally, the author uses the term "level" in the role generally reserved for "factor" in the literature on the statistical design of experiments.

After presenting an analysis of variance based on all of the data, the author states that "a decision was made to eliminate from consideration the burn-in voltages at levels less than the normal life test level of 150% of rated voltage." He proceeds to make statistical tests on the remaining data. Without knowing the reason for the decision to eliminate some of the data, one is likely to be somewhat skeptical of the conclusions. Since no raw data are given the reader cannot check the analysis for himself. However, there is one obvious error in Table I: the degrees of freedom for "Interactions BC" and "Interactions ABC" should be 3 and 12 respectively, instead of 5 and 10 as given. The effect of this error is to make the calculated F values somewhat smaller than they should be, but not sufficiently so to alter the conclusions as to their significance.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The significance of nuclear radiation for military computer reliability

AUTHORS: Paul E. Brown and Alton L. Long, Burroughs Corporation Laboratories, Great Valley Laboratory, Paoli, Pennsylvania

SOURCE: 1961 IRE International Convention Record, Part 6, New York, New York, pp. 115-118, March, 1961

PURPOSE: To point out the detrimental effect of nuclear radiation on the operational reliability of military electronic computers, to assess the usefulness and limitations of existing data on radiation induced damage of components, and to recommend more sophisticated approaches to studies of radiation effects and circuit and systems design to achieve a radiation resistant computer.

ABSTRACT: Use of computers for control purposes in complex weapons systems poses many new problems of reliability not normally encountered in conventional problem solving computers. Military computers may have a very long mission time with infrequent or non-existent opportunities for maintenance, and must function properly in environmental extremes. Sources of nuclear radiation that constitute a significant threat to computer operation are natural radiation such as cosmic rays, solar flares, and Van Allen radiation in space, and artificial radiation attendant with nuclear reactors for propulsion, radioactive power supplies, and nuclear weapons. This radiation compromises computer reliability by producing transient damage to function and permanent damage to component structure. Short intense pulses of radiation produce electrical transients and momentary resistivity breakdown that may cause catastrophic failure. Cumulative dose levels from continuous radiation sources, that may be several orders of magnitude greater than those from pulse radiation, can cause a gradual degradation of electrical characteristics to the point of failure. Unfortunately, solid state devices which are needed for compact equipments are especially sensitive to nuclear radiation.

Although much good work has been reported on the testing of electronic components under nuclear radiation, many reports fail to record data on significant experimental variables. Other studies are so particularized that generalization is not possible, and there is a lack of testing of statistically significant specimen quantities. Moreover, rapid progress in component design renders earlier data obsolete. This state of affairs leads to worst case design or overdesign.

Future studies of radiation effects should be directed towards (a) determining the useful life of components and circuits in a nuclear environment by testing so that the computer life can be confidently predicted, and (b) developing radiation resistant components and circuits. Accurate measurements not only of the dynamic neutron and gamma spectra and total dose but also of the non-nuclear variables are essential. A correlation of dose rate effects with total dose will permit accelerated testing of

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new components and circuits.

Some suggested approaches to computer design for nuclear environments include (a) use of radiation resistant components, (b) use of de-sensitizing circuits during the danger period of pulse radiation, (c) pairing of components that undergo opposite changes under radiation, and (d) shielding of sensitive circuits.

REVIEW: The authors have succeeded in acquainting the reader in a qualitative way with general problems to be considered by designers of computers for use in a nuclear radiation environment. Specialists in radiation effects will probably be aware of most of the ideas presented in the paper. In fact early workers in the Aircraft Nuclear Propulsion program recognized the need for comprehensive radiation measurements in testing and the possible synergetic action of nuclear and non-nuclear environments. As a result the ANP Advisory Committee for Nuclear Measurements and Standards was formed in the mid 1950's, and a radiation effects reactor facility was constructed at Marietta, Georgia. In summary, the paper is directed to conventional system and circuit designers in an attempt to bring to their attention the menace of nuclear radiation to computer reliability. Included in its list of 19 references are 4 bibliographies on radiation effects dated 1956, 1957, 1958 and 1960 that may be of interest to designers. Additional information on transient effects is contained in "Radiation Pulses and Electronics," Nucleonics vol. 18, no. 9, September, 1960, p. 74, by John W. Clark and Thomas D. Hanscome.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transistor reliability estimated with the Poisson distribution

AUTHOR: C. H. Li, Manager of Materials and Techniques Research, General Instrument Corporation, Semiconductor Division, Hicksville, New York

SOURCE: 1961 IRE International Convention Record, Part 6, New York, New York, pp. 119-124, March, 1961

PURPOSE: To suggest an extension of the Poisson equation for use in reliability studies involving transistors.

ABSTRACT: Under a commonly-made assumption the probability of a device (e.g. transistor) having r defects is given by $e^{-c}c^r/r!$, where c is the average number of defects per device. The number c may be written as a product of two numbers u and v. For example, u might represent the number of dislocation lines across a transistor junction per unit junction area, while v represents the junction area. Then c = uv represents the average number of defects (active dislocation lines) per transistor. The proportion R of good transistors (probability of zero defects) may then be written as $R = e^{-uv}$. If the junction diameter is taken as d_i, then the proportion R_i of good transistors having junction diameter d_i is

$$R_i = e^{-u\pi d_i^2/4}.$$

Taking logarithms of both sides of this equation we obtain

$$\log(-\ln R_i) = \log(\pi u/4) + 2\log d_i.$$

Treating u as a constant and plotting $\log(-\ln R_i)$ against $\log d_i$, one should obtain a straight line. The slope of this line should be 2, indicating that the defects are of internal or body type. The intercept with the line $d_i = 1$ may be used in calculating u, the average number of defects per unit area of the transistor junction.

The above is one example illustrating the idea presented in this paper. Several other examples are given. It is indicated that special reliability coordinate paper may be prepared for plotting the lines, and that statistical methods may be applied to make tests on them. The effect of some processing, operating, or testing voltages, temperatures, and times is added to the basic reliability equation. Finally, the simple case is generalized to cover cases where several types of defects exist, having different probabilities of causing transistor failure.

REVIEW: This paper presents a novel idea for application to situations in which the assumptions hold. As the author indicates, it has potential usefulness in the study of failure mechanisms, designing for reliability, and prediction of the reliability of new devices.

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RELIABILITY ABSTRACTS
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TITLE: Does derating improve reliability - longevity?

AUTHORS: William C. Drane and H. L. Benjamin, Light Military Electronics Department, General Electric Company, Utica, New York

SOURCE: 1961 IRE International Convention Record, Part 6, New York, New York, pp. 125-132, March, 1961

PURPOSE: To present evidence which shows that derating does not improve failure rate.

ABSTRACT: A knowledge of the effect of environmental stresses on failure rates is necessary if such rates collected from equipment in use is to be of maximum value in predicting in the design stages the failure rates and longevities of future equipments. Frequently, piece parts are tested at high stress levels, and some kind of power law is assumed to relate the observed failure rates to the failure rates expected under less severe conditions. The underlying assumption is that the part failure rate can be continuously decreased by derating or lessening of environmental stress. It is the thesis of this paper that ordinarily only a small percentage of parts produced are sub-standard in some way. Further, it is contended that derating--the lowering of applied stress--will decrease the probability that sub-standard parts will fail early, thereby decreasing the apparent failure rate. The effect of the lower environmental stresses on the good parts, however, is thought to be an increase in longevity for these parts, but little or no change in their inherent failure rate as long as such parts are operated within reasonable, specified limits.

What then does derating buy you? If you are designing for a short life, derating may postpone the failure of a defective part to a time beyond that in which you are interested. If you are designing for a long life period, the apparent failure rate of your equipment will continue to decrease with time until the sub-standard parts have been eliminated. Derating to lower stress levels stretches out this period, but does not eliminate it. The high percentage of good parts will have their wearout lives extended by derating with practically no effect on their residual failure rates. In a very practical sense, this means that testing an equipment at a high stress level for a short time may eliminate short lived parts. This results in a reliability improvement equivalent to that resulting from derating. Clearly, the acceleration of the failure mechanism of each part by increased stresses can improve reliability only if it does not exceed the minimum capabilities of the good parts.

Another consequence is that parts found to be good can be used at very high stress levels for relatively short periods of time, thus decreasing their expected useful operating lives prior to wearout without a

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significant increase in their probability of failure during the desired operating time. Empirical data on various types of piece-parts subjected to long life are shown to substantiate these hypotheses, and it is proposed that similar data be gathered on additional components so that accelerated environmental testing and longevity prediction can be put on a firm scientific basis. (Authors)

REVIEW: The idea discussed in this paper is definitely worth pursuing; however, the paper could have been more convincing in demonstrating its possibilities. The hypothesis considered is apparently that there is a range of stress in which failure rate is independent of stress, and within this range, changes in stress merely produce changes in longevity, or time to wearout. This hypothesis could have been stated more explicitly. It is not clear what is meant by the phrase "essentially a zero failure rate," for parts, and the term "stress capability" is not defined. It appears that many of the calculations were made on the assumption of a constant failure rate, whereas the slopes on the curves of percent cumulative failures vs. time are observed to be quite changeable. A more detailed explanation of this point would have been helpful. For the reader interested in checking out the numerical results it would have been desirable to state the sample sizes explicitly and at least cite the method which was used. Incidentally, the statement that "It can be concluded here that no significant difference exists ..." implies a stronger conclusion than is normally associated with a failure to reject a null hypothesis. It would be more logical to say "On the basis of the tests made on the available data, we are unable to reject the hypothesis that there is no difference... ."

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of system components under stationary random perturbations

AUTHOR: D. W. C. Shen, The Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, Pennsylvania, and General Dynamics Electronics, Rochester, New York

SOURCE: 1961 IRE International Convention Record, Part 6, New York, New York, pp. 204-209, March, 1961

PURPOSE: To describe an analytical method for calculating the reliability of system components under the influence of random disturbances.

ABSTRACT: The variation of a component parameter with time caused by random disturbing factors arising from manufacture processes and usage may be expressed as a Taylor's series over the time interval within the useful life of the component. Assuming that these disturbing factors are normally distributed and statistically independent, the probability density functions of the Taylor's coefficients are also normal. The two moments involved are the resulting values of the respective moments of the stationary random disturbing factors.

When the coefficient involving the first time derivative alone is considered, the probability density function of the component parameter variation is a symmetrical bimodal curve with zero value at t = 0. The integral of this density function from 0 to a given probable useful life of the component then gives the probability that the useful life of the component lies within the limits specified.

For nonlinear elements subjected to random disturbances, the quasi-linear parameters describing either single-valued or double-valued hysteretic type of nonlinearity are obtained by means of a statistical linearization technique utilizing only the first two moments of the random process. The parameters so determined may provide useful information and criterion for quality control of nonlinear devices. (Author)

REVIEW: This paper is presented as a mathematical discussion, and no effort is made to illustrate the ideas presented. However, as a mathematical discussion it suffers from a lack of clarity and detail. For example, the coefficients in the Taylor's series expansion are functions of the disturbing factors. The latter are assumed to be mutually independent, but this does not necessarily mean that the functions of the disturbing factors are mutually uncorrelated. This is, however, taken to be so without explanation. One would like to see more detail in the derivation of the symmetrical bimodal density function. Incidentally, one of the modes occurs at a negative value of time. It is not clear what practical significance one may attach to a negative value associated with the life time of a component. However, if the function as represented is in fact a true density, the value of the area under the curve corresponding to positive time values is only 0.5, a fact which is disturbing.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Utilization of reliability factors for prediction of spare parts requirements

AUTHOR: Jerome Klion, Rome Air Development Center, Griffiss Air Force Base, Rome, New York

SOURCE: 1961 IRE International Convention Record, Part 6, New York, New York, pp. 210-215, March, 1961

PURPOSE: To propose a technique for the prediction of spare part requirements for electronic equipments as a function of the failure rates of the parts comprising the equipment.

ABSTRACT: Adequate and economic spare parts provisioning is a necessary concern of all users of electronic equipment which must remain operational for a specified period of time with no more than the original spares complement. To date, spare parts prediction has been accomplished in accordance with the available spare parts keys and/or the judgment of the equipment project engineer. Both of these methods depend on previous experience.

In this paper spare parts prediction is developed as a function of failure rate for electronic equipment both of piece part design and of modular design. Equations and graphical procedures are presented to determine the spare parts complement for an electronic equipment when there exists a required probability that the equipment will need no additional spares for a given period of time. The procedure has been demonstrated through application to a representative communications equipment on which a complete reliability study was available. An existing spare parts key was used to determine the spare parts requirement in the conventional manner. A comparison of the results of the two procedures is given.

REVIEW: The procedure described undoubtedly has some advantages over the "average experience" method. However, these advantages may not be as marked as the author claims, if the assumptions underlying the method are taken into consideration. The main assumptions (not stated by the author) are: (1) that failures of components, modules, or blocks are distributed exponentially; (2) that the failure rates of the components in a group, module, or block are additive to yield an over-all failure rate for the group, module, or block; and (3) that the groups, modules or blocks comprising an equipment fail independently, which leads the author to the result that the average probability that the available spares will be sufficient for an equipment is equal to the geometric mean of the corresponding probabilities for the groups, modules, or blocks. These assumptions lead to mathematical tractability, but will not generally be completely satisfied in practice. The proposed method would seem to be most useful for dealing with newly-designed equipment, on which experience has not yet accumulated.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Generalized mathematical model for reliability studies of electronic equipment complexes

AUTHORS: F. P. Randazzo and W. J. Stahl, Systems Analysis and Evaluation Department, ITT Kellogg, Chicago, Illinois

SOURCE: 1961 IRE International Convention Record, Part 6, New York, New York, pp. 216-221, March, 1961

PURPOSE: To describe a generalized mathematical model which can be used for reliability studies of electronic equipment complexes.

ABSTRACT: The availability of a system may be defined as the ratio of the time that the system is operating successfully to the time that the system is tested, in the limit as the testing time becomes large. The mathematical model discussed consists of constructing a functional block diagram of the system, writing a set of Boolean failure equations for all types of failures of the system, determining the probability of failure of each component during an increment of time Δt, determining a component repair priority, and computing the availability. The exponential failure law is assumed. Computer simulation is applied, considering a succession of time increments Δt, and determining for each Δt whether any component failures have occurred. The latter determination is made by taking samples from a set of random, uniformly distributed variates, and comparing the numbers with the probability of failure of the component. The results for a large number of time increments determine the statistics of the system.

REVIEW: This paper is a discussion of some rather elementary points related to component and system reliability. It includes a demonstration that the assumption of an exponential distribution leads to the postulation of a constant conditional rate of failure, a rather well known result. This result is in fact derived twice: in equation (8) and again in equation (12). The Weibull distribution is mentioned, apparently only for the purpose of stating that when the shape parameter is unity, it reduces to the exponential. On the other hand, the Boolean failure equations corresponding to a given block diagram are stated with no accompanying explanation.

The authors might have used greater care in the mathematical presentation. For example, the notation $P_F(t)$ is used to denote the exponential density function in equation (5), and the same notation denotes the cumulative or distribution function in equation (10). A similar comment could be made about the multiple use of A, denoting availability. The constant has been left out of the integral in equation (6). The integral in the denominator of equation (8) has the limits stated incorrectly, so that it does not yield the result indicated for it.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of sequentially operated networks

AUTHORS: George H. Weiss and Meinhard M. Kleinerman, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland

SOURCE: 1961 IRE International Convention Record, Part 6, New York, New York, pp. 222-229, March, 1961

PURPOSE: To present a method for calculating the reliability of sequentially operating networks in terms of switching rules and component reliabilities.

ABSTRACT: A sequentially operating machine is one which has several stages. In order for the machine to operate properly, it is necessary for some component in each stage to operate. The reliability of the network depends on the component reliabilities, the sensing and switching reliabilities, and the switching rules.

This paper considers the calculation of the over-all system reliability in terms of switching rules and component reliabilities. It is shown that the calculation is equivalent to the calculation of state vectors for Markov processes. Results and examples are given for both deterministic and random switching rules.

The method is presented, insofar as possible, by example, rather than in its most general form. Most of the paper is devoted to developing formulae for elements of the transition matrices in terms of sensing and switching reliabilities and rules prescribing switching sequences. The main results are given in the form of prescriptions for the calculation of elements for the transition matrices for exact and random switching rules.

REVIEW: This paper will be of interest to those concerned with the mathematical analysis of the reliability of complex networks, in particular those which operate sequentially. A background of knowledge of stochastic processes, specifically Markov processes, is required, either for understanding the paper, or for adapting the ideas to the analysis of specific systems.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A Markovian model for predicting the reliability of an electronic circuit from data on component drift and failure

AUTHORS: D. M. Brender and M. Tainiter, International Business Machines, New York, New York

SOURCE: 1961 IRE International Convention Record, Part 6, New York, New York, pp. 230-241, March, 1961

This paper is identical in content to the one covered in Abstract and Review Serial Number 51.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: KEWB--A radiation burst test facility

AUTHORS: Robert Stitt and W. M. Haussler, Atomics International, A Division of North American Aviation, Inc., Canoga Park, California

SOURCE: 14 pp., presented at the Western Electronic Show and Convention (WESCON), San Francisco, California, August, 1961

PURPOSE: To describe a facility for exposing components to nuclear radiation burst of very high intensity.

ABSTRACT: It is now a well established fact that brief pulses of intense radiation, such as those produced during a nuclear detonation, can disable, or cause serious malfunction of, most electronic systems even though they are located outside the thermal and shock destruction zones. This fact has given rise to the need for a device which can simulate the radiation environment accompanying a nuclear detonation. Coincidental with the evolution of this need, a family of nuclear reactors has been demonstrated as being capable of producing radiation bursts which, in all important respects, adequately simulate a nuclear weapon. These devices offer additional advantages over field tests involving actual detonation in that they may be operated on a routine repetitive basis at a much reduced cost and under carefully controlled laboratory conditions.

The Kinetic Experiments on Water Boiler (KEWB) reactor has a demonstrated ability to perform in the capacity of a weapon simulator. This reactor is located in the Los Angeles area and is operated by Atomics International for the Atomic Energy Commission. Organizations executing Government contracts can take advantage of its availability if transient radiation resistance requirements are encountered during execution of their contract. The reactor is of the aqueous homogeneous type and produces the shortest duration pulse of any of the thermal neutron reactors operating today. Radiation pulses of varying widths down to 3.0 milliseconds can be obtained with the assembly together with peak neutron and gamma intensities of 3×10^{16} neutrons/cm^2 - sec and 3×10^7 R/sec respectively. Equipment occupying several cubic feet can be located in the immediate vicinity of the reactor core and exposed to these intense radiations. (Authors)

REVIEW: Those engaged in design work for nuclear radiation environments will find this article helpful. The facility is available for use at a total cost of about $400 per day. It should be remembered that this is a "burst" facility. The radiation comes in short, very intense doses. For sustained exposure to nuclear radiation, other facilities would have to be used. Further information on the KEWB reactor and its characteristics may be found in the references listed below, all of

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which are available from Atomics International, A Division of North American Aviation, Inc., P. O. Box 309, Canoga Park, California

REFERENCES: "Capabilities of a high performance solution type pulse reactor," by M. E. Remly

"Laboratory simulation of the radiation environment produced by a nuclear detonation," by John W. Flora

"The response of a water boiler reactor to very fast power transients and linearly increasing reactivity inputs," by R. K. Stitt, E. L. Gardner, J. H. Roecker, and R. E. Wimmer

Brochure 521-B--"KEWB--Experimental studies on the kinetic behavior of water boiler type reactors"

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electrical insulation, Part 2

AUTHOR: (Staff Report)

SOURCE: Electromechanical Design, vol. 5, February, 1961, pp. 45-69

PURPOSE: To provide the electromechanical designer with information pertinent to the proper selection of insulating materials.

ABSTRACT: This digest is a summary of information of particular interest to electromechanical engineers from the papers presented at the Third Annual Conference on the Application of Electrical Insulation held in Chicago in December 1960. The information was selected on the basis of its usefulness to the electromechanical designer in solving insulation problems in advanced applications where insulation systems are required to work reliably in extremely compact packages under a wide range of environmental conditions. The classification of commercially available insulating materials was avoided, whereas emphasis was placed on the description of insulation characteristics, design and selection factors, and methods of test.

The major topics discussed are:

- Types of chemical bonds
- Failure and breakdown values
- Class-F insulations
- Evaluation techniques
- Silicon rubber tapes
- Pressure sensitive tapes
- High temperature components.

In addition there is presented a list of recognized major causes of insulation failure and a check list of important properties (electrical, mechanical, and chemical) in selecting insulating materials. Explanations of the electrical properties relating to insulation resistance are given.

REVIEW: The problem of choosing the best insulation for a given job is clearly important from the standpoint of reliability. This digest will be of assistance with this problem. Those wishing to obtain more detail might wish to refer to the papers from which the summary was made. While these are not listed explicitly as references, they are mentioned in the text, generally giving the titles of the papers and the names and affiliations of the authors.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability testing for commercial instruments

AUTHOR: Staff interview with Clee O. Marsh, Vice President and Chief Engineer, Analab Instrument Company, Cedar Grove, New Jersey

SOURCE: Electronic Equipment Engineering, vol. 9, January, 1961, pp. 60-63

PURPOSE: To describe the reliability tests for a commercial oscilloscope.

ABSTRACT: Commercial requirements are less severe than military ones and reliability testing can be restricted to laboratory and production line conditions. An oscilloscope must withstand heat runs, altitude tests, vibration tests, power line frequency tests, an operational environment test, and a packaging test. They are run in that order.

For the initial heat run as many as 40 thermocouples are installed in critical spots. The equipment is operated at the highest rated line voltage and lowest rated line frequency. All instrument controls are set to produce maximum power dissipation. The run begins at room temperature and continues until a new equilibrium is reached. Transient temperatures are carefully watched. In convection-cooled instruments careful attention must be given to the air flow paths.

The altitude test is similar to the heat test. The altitude is raised slowly; temperatures, voltage breakdown and corona are monitored. The instrument is rated at 10,000 ft and is tested to 12,000 ft. The altitude is finally increased to 24,000 ft in order to find the weak spots.

The vibration test also is performed with the equipment operating. It starts with a 1/2 inch peak-peak constant amplitude from below 5 cps up to an acceleration of 3.3g; from there to 50 cps it is run at constant acceleration. Three sweeps in each of the three planes are run and performance is continually monitored. If failures occur, the test is stopped and appropriate action taken. Next, the covers are removed and the frequency range is again swept. This time, part resonance is looked for, and if it occurs, the unit is tested there for 10 to 15 minutes to be sure that the resonances do no damage.

The instrument is run over the range from 50 to 400 cps line voltage and all critical points are monitored. The criterion for failure of a power supply is excessive hum. In this test, the line source should be a good sine wave.

For the operational environment test the instrument is put through a small program of temperature and humidity cycles. The final test is the standard "National Safe Transit" test. It is a series of vibration tests followed by controlled drops--during which the instrument

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is packaged as for shipping.

If any of these tests are performed outside the company, the electrical and mechanical engineers should be on hand to see the tests and make any necessary on-the-spot decisions.

REVIEW: These tests seem to be for the purpose of uncovering design or construction weaknesses. No attempt has been made to measure the life under any set of conditions. Very little has been published on the testing of commercial instruments so it is impossible to compare these tests with others.

It would be a good idea for EIA to set up some standard tests for equipment of this nature. Then manufacturers could advertise that their equipment met certain environmental tests. At present, almost everyone claims high reliability with little quantitative data to back it up.

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TITLE: How to avoid vibration test failures

AUTHOR: Daniel Schochet, Assistant Chief Engineer, Associated Testing Laboratories, Wayne, New Jersey

SOURCE: Electronic Equipment Engineering, vol. 9, February, 1961, pp. 75-78

PURPOSE: To help avoid some vibration troubles and to describe some vibration tests.

ABSTRACT: The most frequent cause for qualification test failure is vibration. Equipment failure during vibration testing will generally fall within one of the following categories: noise and intermittent circuit malfunctions, short circuits and component burnout, and mechanical failure. Vacuum tubes, relays, potentiometers, synchros and other devices using contacts are the most susceptible to noise and intermittent operation. Where feasible, vibration isolators will help. Long lengths of wire (unsupported) or large chassis areas may vibrate. This causes abrasion or possible short circuits during the motion. Structural failure is common, since at resonances loads may be 100 times normal. Brackets tend to break at sharp corners, especially on transformers which are heavy. Loose components, no lock washers, etc., will surely cause failures. Many parts should not be supported by their leads. Preliminary vibration testing of subassemblies will be a big help.

In sine wave testing, peak-peak amplitude and maximum acceleration are usually specified for low and high frequencies respectively. Resonance tests are performed by slowly varying the frequency at low amplitude and noting any improper movement or malfunction. Resonance endurance tests are then performed, often in combination with high or low temperatures. Random vibration testing is relatively new. The spectral power density must be specified. An accelerometer can be mounted on the equipment and its output analyzed to determine if the conditions are proper. Considerable care is necessary to make sure the vibration machine has a flat response.

REVIEW: Vibration is certainly an important consideration in design for reliability and this paper can serve as an introduction for those not familiar with the subject. It is worth mentioning explicitly that the equipment should be operating during the test.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability design nomograph

AUTHOR: Alan O. Plait, Senior Engineer, Reliability Design Department, Magnavox Company, Fort Wayne, Indiana

SOURCE: Electronic Equipment Engineering, vol. 9, May, 1961, pp. 63-64

PURPOSE: To present a chart for calculating reliability from mean failure rate and operating time.

ABSTRACT: Parts reliability is usually expressed in percentage of failures per 1000 hours. A table gives the failure rates of 22 commonly used components. To calculate system reliability, a simple parts count is made, failure rates are assigned to each part, and the failure rates are added. The failure of any part is assumed to cause system failure. During the early life of a component, the failure rate is high; then it settles down to a constant level; finally it rises again as the part enters the wear-out period. This discussion assumes that the component is in the middle stage of its life. The reliability is calculated from the exponential law. A nomograph is provided for making this calculation, given the failure rate and the operating time. It is interesting to note than an equipment with mean time between failures (MTBF) of one hour and operated for one hour would have a reliability of only 36.788%.

REVIEW: This is a very elementary article. The need for a nomograph to make a simple exponential calculation is not clear. For practical cases where the reliability is over 90%, the simple linear approximation based on the series expansion is adequate, in view of the usual accuracy of the original data. The use of five significant figures in failure rate and MTBF calculations is hard to justify. There is a minor difficulty with the units in the reliability equation. The final example can be stated more generally: any equipment operated for a time equal to the MTBF will have a reliability of (100/e)%, if the exponential failure law applies. The article does not mention that parts may fail by drifting outside the required tolerances, or they may fail catastrophically. Presumably the table refers to catastrophic failures. A revision of the table based on reference (1) was published in the June 1961 issue of Electronic Equipment Engineering, p. 40. Data on component failure rates may be found also in reference (2).

REFERENCES: (1) RADC Electronic Reliability Notebook, Supplement 1, OTS Publication PB 161 894-1 (Available from U.S. Government Printing Office, price $3.50)

(2) "Reliability growth prediction during the initial design analysis," Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 380-393, January, 1961 (See Abstract and Review Serial Number 12.)

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electron-beam welding for reliable interconnection

AUTHOR: (Editorial matter)

SOURCE: Electronic Equipment Engineering, vol. 9, September, 1961, pp. 48-50

PURPOSE: To describe the properties of electron-beam welded joints.

ABSTRACT: Electron-beam machine technology uses a controlled high-density stream of electrons to weld, melt, or cut practically all known materials, including ceramics. In any microminiaturizing program there are places in which electron-beam techniques are the preferred or sole method of fabrication. Beam voltages are about 150kv, spot diameters are 0.5 to 5 mils, and power densities are up to 10^{10} watts/in^2.

A packaging concept was designed for an all-welded, hermetic assembly. This "Optimized Microminiature Electronic Circuit" (OMEC) has

(1) planar ceramic circuit boards,
(2) a planar ceramic two-sided interconnection board, and
(3) a hermetic header and cover.

To show feasibility, a demonstration system was designed and several units were built. The unit contains an eight-bit serial adder, two eight-bit number generators and a clock packaged in a hermetic container. Some of its properties are: volume: 1.25 cubic inches, weight: 45.3 grams, packing density: 258,000 parts/cubic foot, electron-beam welded joints: more than 1200. The units have withstood severe shock and vibration tests with no evidence of weakened or failed joints. Metallurgical tests also showed the joints to be very good. It is believed that this new technique offers an increase in electronic system reliability.

REVIEW: This is a useful article for keeping engineers up-to-date on methods of construction. It could have been improved if references for further reading were given. No failure rates are quoted.

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

TITLE: Determining optimum burn-in for capacitors

AUTHOR: Lawrence D. Hines, Corning Glass Works, Bradford, Pennsylvania

SOURCE: Electronic Industries, vol. 20, September, 1961, pp. 105-107

Except for minor differences in wording and the omission of sections headed "Conclusions," and "Summary," this paper is the same as the one covered in Abstract and Review Serial Number 80.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Redundancy techniques in reliable power supply design

AUTHORS: Donald A. Paynter and Vernon P. Mathis, Electronics Laboratory, General Electric Company, Syracuse, New York

SOURCE: 12 pp., presented at the International Solid State Circuits Conference, Philadelphia, Pennsylvania, February, 1961

PURPOSE: To present a general approach to the improvement of the reliability of power supplies through the use of redundant semiconductor switches.

ABSTRACT: Power supplies are considered to be among the most critical elements in any electronic signal processing system, and the semiconductor switches used are assumed to be one of the most unreliable elements in the power supply unit. A general treatment of switch redundancy techniques to improve reliability is presented. The application of these techniques to two different power converters is illustrated.

The use of redundant semiconductor switches in converter-type power supplies and regulators is considered to be feasible in practical circuits. Known concepts (reference cited below) may be extended and modified to enable the prediction of the mean-time-to-failure for the redundant units. Quantitative statistical information is needed on the failure modes of the devices employed before an optimum redundant configuration can be designated.

REFERENCE: Moore, E. F. and Shannon, C. E., "Reliable circuits using less reliable relays," Journal of the Franklin Institute, vol. 262, September-October, 1956

REVIEW: This topic is likely to be of interest to designers. However, the report suffers from brevity and lack of detail (nine of the 12 pages being devoted to figures). Probably the authors went into more detail in their oral presentation.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability--Where do we go from here?

AUTHOR: James N. Davis, Deputy Assistant Secretary of Defense for Production Management, Washington, D. C.

SOURCE: Industrial Quality Control, vol. 18, September, 1961, pp. 4-7

PURPOSE: To survey the present state of industry-Government relationships in the field of reliability and to point out what is needed.

ABSTRACT: Looking at the past ten or twelve years, one can view optimistically the trend toward increasing attention of higher echelons of leadership to the problems and cost of increasing reliability of Defense systems. This trend is moving likewise in the direction of quantified requirements as a part of specifications, although we may not be satisfied with the rate of progress. More attention can be expected on quantifying specifications for both components and systems bearing on reliability in order to improve the understanding between industry and Government, to clarify our mutual objectives and to insure that the cost of reliability is applied rationally to the problem. Specifically, the Darnell Report has been a milestone, and we in the Government must convert its recommendations to actions beneficial to our industry-Government relationship.

Government can help stimulate top management's interest and attention in quality control, reliability and training of personnel, and should continue to do so. The interest in reduction of failure rates is of mutual interest and indistinguishable between Government and industry. Process control, training of workers at all levels who participate in the handling and fabrication of high-reliability parts is needed, and we are seeking ways to encourage it. Accelerated action is needed to translate statistical theory into usable tools for planning and executing reliability tests. It can be stated clearly that the Secretary of Defense desires that the statement of work as exemplified by the specifications and the content of contracts be clarified so that industry-Government understanding of the task at hand be improved and unnecessary costs be eliminated. (Author)

REVIEW: The two points that are emphasized (improvement in Government specifications and improvement in industry performance) are very important. Just which is the more critical is a matter of some controversy, although the position presented here is carefully neutral. An especially good point is the questioning of the need for continuing to treat reliability as something separate and distinct from the product. A sign of real maturity of the industry and the reliability discipline will be seen when they are able to deal with reliability on the same level as other facets of quality.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Basic philosophies in reliability

AUTHOR: T. A. Budne, Statistical Engineering Consultant, Great Neck, New York

SOURCE: Industrial Quality Control, vol. 18, September, 1961, pp. 21-27

PURPOSE: To give some background in the development of the reliability discipline.

ABSTRACT: There are several measures of reliability which are important. Among these are probability of survival, availability, maintainability and failure rate. The definition of a failure is critical in applying these terms. Several fundamental premises stand out in the prevailing reliability philosophy. First, reliability is basically a design parameter. The design must be translated into hardware without losing any of the potential reliability. Reliability should be predicted at each successive design stage in order to go intelligently ahead. Underlying the reliability prediction technique is a basic premise of constant failure rate. Experience shows that electronic mortality rate has a high initial value, then a low constant section and finally a high value during wearout. The reliability is completely determined by the constant failure rate section. Various sampling methods plus the usual techniques, principles, and practices of the quality engineer are combined to ensure the reliability of equipment. Management considerations are important too; in fact, the problems of unreliability in complex equipment today are very largely management problems.

More progress could be made if less effort and time were devoted to establishing parts reliability and more to improving it. Two uninformed, unconstructive and discordant points of view are (1) reliability is nothing more than quality with the added dimension of time, and (2) quality control is an inspection operation. The achievement of highest reliability depends on the kind of totally organized effort discussed here and on the mutual understanding and cooperation between design, manufacturing, and quality personnel.

REVIEW: This paper has ideas similar to many in the philosophical reliability papers and articles. The following two examples, however, illustrate the lack of consistency. (1) The human mortality curve is said to be reasonably constant below the two deaths/1000 rate. Yet it seems to vary by a factor of two or three in that range--and would hardly be called constant. (2) The author says that much of the time taken to establish component failure rates should be spent on failure rate improvement. This completely ignores the problem of knowing whether or not an improvement has been made.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiographic and polarographic testing of electronic components

AUTHORS: S. DiLauro and F. K. Kiefer, Sperry Gyroscope Company, Great Neck, Long Island, New York

SOURCE: Nondestructive Testing, vol. 19, pp. 261-263, July-August, 1961

PURPOSE: To show how X-ray pictures and photoelastic analysis of stress solved some problems in the manufacture of mercury-wetted relays.

ABSTRACT: Mercury-wetted relays were the most vital component in a particular digital computer and they were causing trouble. The relay consists of four mercury-wetted switches, hermetically sealed in pressurized hydrogen. Each switch has a moving armature welded to the stem at the bottom of the vial and four point contacts supported by wires which are sealed at the upper end of the vial. A coil surrounds the switches. The whole assembly is potted in wax and sealed in a steel container. The predominant defects were: (1) low insulation resistance, (2) broken vials, (3) amalgamated contacts, (4) shorted contacts, (5) coil-to-case shorts, (6) loose solder, (7) improper positioning of coil, (8) improper welding of the capsule stem.

Vial breakage and leakage was caused by a poor seal between the metal stem and the glass. The vials are pressurized with hydrogen. This property can be used as a check for poor seals. If the units have good seals, the internal pressure will be high enough to put strains in the glass. The vial is immersed in a liquid with the same nominal index of refraction. A photoelastic method developed by Riney of Bell Telephone Laboratories is used to measure the amount of strain. A sample of vials from each production run is tested in this way.

X-ray photos show the position of the switches, wires, and coils inside the case. Loose globs of solder and mercury will also show up. Some of the positioning errors cause shorts or vial breakage.

This program evolved a new, higher quality, lower cost technique of manufacture. It pinpointed the true cause of failures and resulted in a major rewrite of the performance specifications.

REVIEW: The article is limited to mercury-wetted relays, rather than being as general as the title. It was adapted from a talk and suffers some of the disadvantages inherent in that process. There is sufficient detail, however, to provide a good insight into the two techniques that were used. Component development engineers will find this a worthwhile paper.

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R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

TITLE: Redundancy and the detection of first failures

AUTHORS: Dwight C. James, A. Howard Kent, Jr., and John A. Holloway, The Martin Company, Denver, Colorado

SOURCE: 17 pp., presented at the Western Electronic Show and Convention (WESCON), San Francisco, California, August, 1961

PURPOSE: To review some techniques for circuit reliability improvement and to present some new ideas on majority vote redundancy.

ABSTRACT: The methods of reliability improvement can be divided into five groups: component part improvement, stress level reduction, circuit simplification, maintenance and production techniques, and redundancy. An example is given of the possible improvement for the first three together--a factor of 21 in failure rate. An important consideration in determining the equipment reliability is the failure rate when the equipment is not operating.

After all other methods of improving component and circuit reliability have been used, then redundancy may be considered. In redundant circuits, the mode of failure is very important. For example, if the component always fails by shorting, then putting two in parallel will produce no improvement, but putting them in series will. The conventional equations for series, parallel, series-parallel and paralled-series configurations are derived.

Majority Voting may be used for redundancy in many cases. One difficulty is the noting of failures when they occur since they do not affect the operation of the system. The concept of Dissenting Vote Indication (DVI) is introduced and some circuits are shown for its use. In this way, failures can be repaired before the system breaks down. This feature (DVI) is considered to be an advance in the state of the art.

REVIEW: The introduction of DVI to Majority Voting (MV) is worthy of serious consideration, although it does introduce extra complexity into the circuit.

Some of the limitations and drawbacks of this presentation are:

(1) It is limited to the exponential case (without pointing out other possibilities).

(2) In the example showing the combined effect of component part improvement, derating, and simplification on system reliability improvement, the calculation is in error. In effect it is incorrectly assumed that the weighted total is equal to the unweighted total multiplied by a weighted mean of the weights. As a result of this, the figure quoted

as 4.38 should in fact be 3.27.

(3) In the "redundant" section, the failure rates of surviving components are assumed to be independent of the number of failed components. If two resistors are in parallel, the power dissipation in the survivor will certainly be affected by the failure of its mate. This can easily change the life of the survivor.

(4) Numerical examples are used to "prove" the truth of general statements.

(5) The effectiveness of the majority vote circuit depends on the mode of failure of the components. If the circuit were to use non-capacitor coupled logic, the next to the last stages could fail in such a way as to cause failure of the system.

(6) If the last stage of the MV system can be made good enough not to need the DVI system why could not the original stage that the system replaced be made that good?

(7) A full page in the appendix is devoted to proving that the binomial coefficients are equal to the numbers of combinations of n things taken k at a time. This is a fairly well understood point.

(8) The footnote on page 11 contains several uncorrected errors.

(9) The calculation of reliability for the MV circuit is all done with numbers rather than with an algebraic expression. This prevents evaluation of the influence of the various terms. No mention is made of the origin of the chosen failure rate nor of the effects (discussed early) of open and short failures on the system.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The optimum allocation of spare components in systems

AUTHOR: Donald F. Morrison, National Institute of Mental Health, Bethesda, Maryland

SOURCE: Technometrics, vol. 3, pp. 399-406, August, 1961

PURPOSE: To present a solution to the problem of allocating a fixed number of spare components between two subsystems to provide maximum reliability over some specified interval of time.

ABSTRACT: This paper considers a system whose components may be divided into two subsystems, each containing components whose lives are exponentially distributed but with different scale parameters. Failure of any component will cause the entire system to fail. Under the requirement that components of one type of life distribution are not interchangeable with those of another, each subsystem is assigned a store of similar spare components. System failures are corrected by successively replacing failed components in the subsystems from the appropriate stores of spares until a failure occurs with no spare available for substitution. At this "final failure" the entire system is discarded.

Charts are presented for allocating a fixed number of spares between the two subsystems for maximum reliability on some specified interval of time. Expected system life is also taken as a maximand, and a table is given of combinations of spares of each type that maximize that quantity. Some attention is devoted to the effect of non-exponential component densities upon these optimum strategies.

REVIEW: The ideas presented in this paper may well be of interest to design engineers working on systems for which the provision of limited stores of spare parts is feasible. The paper treats the subject from a mathematical-statistical point of view, and is not, per se, concerned with the application of the results to any particular system. The author includes a brief discussion of relevant earlier work, together with references, which should prove useful to anyone wishing to look into this topic.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of components exhibiting cumulative damage effects

AUTHOR: George H. Weiss, U.S. Naval Ordnance Laboratory, White Oak, Maryland (present address: Institute for Fluid Dynamics and Applied Mathematics, University of Maryland, College Park, Maryland)

SOURCE: Technometrics, vol. 3, pp. 413-422, August, 1961

PURPOSE: To study several simple models which incorporate random operating and environmental effects in the derivation of reliability functions and their moments.

ABSTRACT: Several models of systems which include hereditary or environmental effects are analyzed. The problem considered is the following: given the conditional reliability function (probability of being operable at time t conditional on operability at an earlier time), to find the unconditional reliability function (absolute probability of operability at time t).

The first model discussed involves hereditary effects by postulating that the conditional reliability functions depend on the times of operation of the mechanism. In order to render the model tractable, it is assumed that only the last time of operation entered into the expression for the conditional reliability function, and that this function at any time t depends only on the difference between the two times. An integral equation is written for the reliability function. If the times of operation follow a Poisson distribution, specific results may be derived since the integral equation reduces to one of the convolution type and can be solved by Laplace transform techniques. The solution for the unconditional reliability function is given both as a function of time and as a function of the number of operating cycles. In the latter case the failure distribution is found to be a simple geometric one. The second model consists of a system which is capable of being in one of a number of operative states, or in a state of failure.

These models are related to semi-Markoff processes which have recently been studied in connection with reliability, Geiger counter problems, and inventory problems.

REVIEW: This is a mathematical paper which will be of more interest to the theorist than to the reliability engineer.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An analysis of some relay failure data from a composite exponential population

AUTHORS: R. R. Prairie and B. Ostle, North Carolina State College and Arizona State University

SOURCE: Technometrics, vol. 3, pp. 423-428, August, 1961

PURPOSE: To present an analysis of some life test data on relays, using a model which assumes that the hazard rate is a step function.

ABSTRACT: In many practical life test situations, more than one failure mode may be operating. An example of this is the case where the units under test are subject to a high early hazard rate followed by a lower hazard rate which persists after the weaker units have failed. Miller [1] has considered the case in which there are two groups of units, one of which represents the general quality of the product while the second may be classed as early failures.

This paper reports an extension of the method of Miller to the case of three hazard rates with unknown points of transition (i.e., unknown points of time at which the hazard rate changes). Estimates of the five unknown parameters (the three hazard rates and the two transition points) are obtained by the method of maximum likelihood. A numerical illustration is given.

REFERENCE: [1] Miller, R. G., Early failures in life testing, Journal of the American Statistical Association, vol. 55, pp. 491-502, September, 1960

REVIEW: This paper provides a useful extension to the available models for use in life testing. The authors point out that a generalization of their results to situations involving more than three hazard rates and two points of transition is straightforward. It appears that the authors have found their method to yield good results on a set of observed data. There may well be many life test situations in which this method will be found to be applicable.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimating a mixed-exponential response law

AUTHOR: F. J. Anscombe, Princeton University and Mathematica

SOURCE: Journal of the American Statistical Association, vol. 56, pp. 493-502, September, 1961

PURPOSE: To derive an estimation procedure for the two parameters of a mixed-exponential response law.

ABSTRACT: This paper is concerned with the estimation of the parameters of a mixed-exponential response law, given some sample observations. Two alternative laws are considered, each having two parameters. The first law expresses the proportion F(t) of the population who have responded within time t in the form

$$F(t) = (1 - e^{-\alpha t})\xi.$$

The second law states that

$$F(t) = 1 - (1 + \lambda t)^{-\nu}.$$

The problem has been encountered in the context of market research in estimating the "penetration" of a market by a new product; and it is therefore described in those terms. But mathematically identical problems arise also in life testing and in fisheries research. The problem is similar to the well-known one in toxicology of fitting a response law (logistic, probit, or whatever) to dose-mortality data, with the exception that in the present case the points on the empirical response curve are not independent, the basic sampling distribution being multinomial instead of independent-binomial. In regard to statistical methodology, the paper aims to illustrate the role of the likelihood function in estimation. Whether the likelihood function has a "large-sample" appearance depends not only on the sample size but on the parametrization. (Author)

REVIEW: This is a mathematical paper which will be of interest to the theorist rather than to the design engineer. The topic has relevance to the field of life testing, as the author points out. It would be applicable in situations in which an unknown proportion of the population is subject to an exponential failure law with an unknown rate, whereas the rest of the population is not subject to failure.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relays in space systems

AUTHORS: W. Thomas Weir and John S. Youtcheff, Missile and Space Vehicle Department, General Electric, 3198 Chestnut Street, Philadelphia 4, Pennsylvania

SOURCE: 12 pp., presented at the Ninth National Conference on Electromagnetic Relays, Stillwater, Oklahoma, April,1961, General Electric MSVD report

PURPOSE: To discuss the relative merits of utilizing military, telephone, and reed relays in space environments.

ABSTRACT: Specifications for relays can be established when the environmental stress levels and equipment functional requirements are fully known. Environments to which space systems are subjected vary from vibration during preflight operation to possible salt spray during the recovery phase of flight operation. Other significant environmental stresses that can be analytically estimated are temperature, pressure, acceleration, solid particles, radiation, acoustic noise, shock, humidity, sand and dust, and fungus.

The three basic relay types considered for space application are the military (m), telephone (t), and reed (r) relays. For reasons presented in the paper, the relays are ranked in order of desirability for each of the following applications: for operational life under normal conditions, r, t, m; under vibration and high acceleration, m; under heavy contact load, t, m, r; for small size and low weight, m; for low cost, t or r; for extended operation in the space flight phase after launch, r.

REVIEW: The authors' discussion of the operational environment is highly general and is essentially a correlation of the above mentioned environments with the flight profile of a typical space system. Similarly, the advantages and disadvantages of various types of relays are presented in a qualitative manner, e.g., graphs displaying failure rate, rating, cost, size and weight have no ordinate scales. This paper will serve as a useful guide for acquainting a designer with factors to be considered in selecting relays for space systems. Additional information on environments can be found in Satellite Environment Handbook, Stanford University Press, May, 1961, by F. S. Johnson, Editor

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A study of discharge transients in relays with grounded cases

AUTHORS: Charles P. Nunn and Reinhold Halbeck, Filtors, Inc., Port Washington, New York

SOURCE: 17 pp., presented at the Ninth National Conference on Electromagnetic Relays, Stillwater, Oklahoma, April, 1961, Filtors Relay Research Monograph

PURPOSE: To report the experimental results and conclusions of an investigation of high current arcs between relay contacts and grounded cases in miniature and crystal case relays.

ABSTRACT: Miniature and crystal case relays have been completely destroyed by high current discharges between the contacts and relay cases at ground potential. Tests on 15 types of relays with a contact load of 1 to 2 amperes at 115 volts rms, 60 cps, showed that an arc discharge would usually occur within 1 to 100 operations. 0.1- to 0.25-ampere fuses in the ground circuit leading to the case normally limited the peak current to a nondestructive value of approximately 40 amperes. By suitably reducing the contact current or voltage, no arcs to the case were encountered--for arcs to occur, both the current had to exceed 0.25-0.5 ampere and the voltage had to exceed 30-50 volts. These results were largely independent of the rate at which the contacts were operated (10-400 per minute) and the frequency of the a-c power (60 and 400 cps). Arcs between the contacts and case did not occur in relays switching direct current power loads when the case-contact potential difference was below 50 volts or when the arc life on the separating contacts was shorter than 0.5-1.0 millisecond. For both a-c and d-c power loads the arcing occurred when the case potential was sufficiently positive relative to the contact potential. Tests were made on over 100 relays with a majority in the hermetically sealed condition.

It is believed that the breakdown mechanism is due to electrons and ions diffusing from the arc between the contacts, acquiring additional energy in accelerating toward the case, and ionizing the atmosphere, thereby creating a self-sustaining discharge. By proper design with teflon insulation, a relay was constructed that has operated 10^5 times without discharge under 2-ampere, 115-volt a-c, grounded-case conditions. An alternate design utilizing arc-quenching gases shows some promise.

REVIEW: This paper contains useful quantitative information on the permissible range of circuit parameters to avoid arcing between the contacts and the grounded case of a certain class of relays. The method of testing can be readily applied by relay users to their specific problem. It would be interesting to investigate whether a grid enclosing the contacts and slightly negative relative to them would inhibit the initiation of the discharge.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Annealing of reactor radiation damage in lead and bismuth tellurides

AUTHORS: J. C. Corelli, R. T. Frost, and D. M. Amorosi, General Electric Company, Knolls Atomic Power Laboratory, Schenectady, New York

SOURCE: KAPL-2159 AEC Research and Development Report, 66 pp., July, 1961

PURPOSE: To report some results of an irradiations program dealing with reactor radiation damage in thermoelectric materials.

ABSTRACT: Reactor irradiations of specimens of n-type and p-type lead and bismuth tellurides were carried out to neutron doses of 5×10^{19} fast ($E > 1$ Mev) neutrons/cm^2 and 6×10^{20} thermal neutrons/cm^2 at an irradiation temperature of $60 \pm 20^{\circ}C$. Comparison of pre- and postirradiation electrical properties of duplicate specimens irradiated with and without cadmium shields indicated that, for these exposures, the principal damage is caused by fast neutrons. This confirms earlier results [KAPL-2091] obtained from similar specimens irradiated to fast and thermal neutron doses one-quarter as great as in the case of the experiment reported here. Comparison of the results of the two experiments indicates that damage caused by fast neutrons tends to saturate at a dose of 1 to 2×10^{19} fast neutrons/cm^2. Hall coefficient data indicated that the major portion of damage to electrical and thermal conductivity and Seebeck coefficient of n-type PbTe could be attributed to depression of electrical carrier concentration. This is tentatively attributed to a bombardment-induced trapping level 0.037 volt below the bottom of the conduction band.

Annealing experiments performed with the irradiated n-type PbTe indicated complete recovery of measured properties for the cadmium-shielded specimen at temperatures in the range of 140 to $200^{\circ}C$. Small unannealable changes in electrical properties of the unshielded specimen are, within experimental and calculational uncertainties, attributable to increases in carrier concentration caused by transmutation-induced increases in iodine doping level. Similar results were obtained in the case of n-type Bi_2Te_3. Damage to p-type PbTe was not completely removed by annealing. Cold-work experiments carried out on this brittle material indicate that the unannealed damage may be caused by effects associated with the encapsulation procedures. The largest changes in electrical properties before annealing were observed in the case of the initially undoped p-type Bi_2Te_3, in which Seebeck and Hall coefficients showed a reversal in sign as a result of the irradiation. (Authors)

RELIABILITY ABSTRACTS
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REVIEW: The authors have presented a thorough and lucid account of their experiments on semiconductors of current interest for thermoelectric power generation. The reviewer notes that the slope method used to obtain the energy of the 0.037-volt trapping level yields the temperature-independent component and does not include the component linear with temperature, should one exist. The report contains many good data on isothermal annealing of the resistance and the Hall and Seebeck coefficients, and their dependence on temperature. The physical interpretation and discussion of the measurements appear valid. Derived in the appendix is a geometric correction factor for Hall measurements in cylindrical specimens.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transient effects of pulsed nuclear radiation on electronic parts and materials

AUTHORS: H. J. Degenhart and W. Schlosser, U.S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey

SOURCE: IRE Transactions on Component Parts, vol. CP-8, pp. 123-128, September, 1961

PURPOSE: To present experimental results on the transient behavior of electronic components induced by pulsed nuclear radiation.

ABSTRACT: Nuclear radiation induced transient changes in the electrical characteristics of electronic parts and materials obtained in recent experiments at the GODIVA II pulse reactor are described and discussed. The electronic parts investigated and monitored during exposure include: coaxial cables; resistors of various types and manufacture, ranging in value from 100 ohms to 1 megohm; sensistors; capacitors, ceramic and tantalum; rectifiers, silicon and selenium; and magnetic cores, ferrite. Most of the parts during exposure show transient parameter changes which exceed the tolerance values and then recover generally to the nominal value within two to five msec. Curves are shown of the time dependence of resistance changes, leakage currents in capacitors, inductance changes in ferrite cores, and forward voltage drops and reverse currents in rectifiers. The peak fluxes were of the order of 10^{17} n/cm^2-sec for neutrons and 10^7 rad/sec for gammas. (Authors in part)

REVIEW: The graphs contained in the paper provide useful quantitative information on the time dependence of the parameters investigated. The results for resistors and semiconductor diodes are similar to those previously reported (see, e.g., J. W. Clark and T. D. Hanscome, Nucleonics, vol. 18, no. 9, p. 74, 1960). The data on ferrites support Clark and Hanscome's conjecture that ferrites would exhibit transient behavior when exposed to pulsed radiation. The authors do not report specific neutron and gamma flux intensities, spectral information, accumulated dosage or length and shape of the radiation pulse. No mention is made of the possibility that charge scattering (e.g., due to gamma collisions) can cause extraneous currents. This current should be proportional to the physical size of the components and has been observed by previous investigators. The equivalent circuit in Figure 6 for a resistor should include a time dependent current source in series with R_o to represent the effect of this current. If charge scattering is not negligible, analysis of data from the resistance measuring bridge circuit in Figure 2 in the usual manner would lead to erroneous resistance changes for Figure 5. The transient currents in the capacitor may be due in part to charge scattering. It seems unlikely that the polarization in the dielectric would change significantly.

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In a private communication the senior author of this paper indicates that dosimetry data were omitted because of their classified nature at the time of the presentation. He goes on to say "...these data and other information, including more references are presented in a USASRDL Technical Report #2200 titled "Pulsed Nuclear Radiation Effects on Electronic Parts and Materials" by H. J. Degenhart and W. Schlosser. Furthermore, seemingly lacking data on pulse shape and spectrum may be found and extracted from references #2, 3, 4 in the paper and from "Irradiation of Semirad at Godiva II" by Harry M. Murphy, Jr., USASRDL, Ft. Monmouth, New Jersey, Technical Report #2185, 15 February 1961. Copies of above cited reports may be obtained from ASTIA, Arlington Hall Station, Arlington 12, Virginia." In the same communication the author makes the following comments regarding the possibility of charge scattering. "Results of subsequent experiments conducted in August of this year were indicative, more quantitatively, of such nuclear radiation induced extraneous currents which have been suspected earlier. Blank potted cables and resistors that were connected to their respective detecting circuits (as shown in the paper) without an external voltage source applied to them showed transient voltage peaks at their circuit output to the oscilloscope during the radiation pulse. Also, the voltage dependence of the transient effects in cables were studied over a wide range of positive and negative voltage applied to these cables. Evaluation of these data is presently in progress and the final results will be found in a forthcoming USASRDL Technical Report."

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimating reliability trends from evaluation of weapon systems tests

AUTHORS: A. Steinberg, E. L. Bombara, and S. M. Jacks, Army Rocket and Guided Missile Agency, Redstone Arsenal, Alabama

SOURCE: Army Rocket and Guided Missile Agency Reliability Report, 11 pp., June, 1961

This report is the source of the paper covered in Abstract and Review Serial Number 43. The report contains a table showing the computation of system reliability for the purpose of showing trends, which does not appear in the published paper. Except for this and some minor differences in wording, the two texts are the same. A correction has been indicated for the error noted in Review Serial Number 43.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Micromodule reliability status report

AUTHOR: D. T. Levy, Radio Corporation of America, Semiconductor and Materials Division, Somerville, New Jersey

SOURCE: 5 pp., presented at the 1961 IRE International Convention, abstracted in 1961 IRE International Convention Record, Part 6, New York, New York, p. 253, March, 1961, Radio Corporation of America Publication No. ST-2106

PURPOSE: To show the accomplishments of a micromodule reliability program.

ABSTRACT: Missiles and satellites need component failure rates on the order of 0.01% to 0.001% per 1000 hours (at 90% confidence). One goal of the Army micromodule program is a 10-element module with a mean time to failure (of the module) of 75,000 hours (90% confidence--while the paper says "10%," it is probably a misprint). The main goal of the program is to establish adequate reliability management and engineering techniques as an integral part of the micromodule operations.

Continuous in-process testing and data tabulation allow recognition of failure mechanisms which, in turn, facilitates corrective action. Features which can be consistently reproduced in automated facilities are used in design. These include: ceramic substrates, thorough cleaning for minimum contamination, reliable capacitors (no waxes, papers or other organics), and hermetically sealed semiconductor devices in the new flat package. Proper management includes effective design reviews and centralized responsibility; these insure a closed-loop feedback from testing to faults to corrections to more testing, etc.

The following table shows the results so far for passive elements.

Component		Catastrophic Failure Rate (%/1000 hours)	
		Conventional	Microelement
Resistor:	utility	0.12	0.159*
	precision		0.186
Capacitor:	gen. purpose	1.00	0.147
	precision	1.00	0.060
	electrolytic	3.00	2.300
Inductor		0.30	0.700*

* no failures; one assumed

The following table is given for active components.

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Element	Element hours x 10^3	Number of units	Failures
1N277	752.0	340	0
1N643	366.5	131	0
2N384	206.0	97	2
2N404	814.5	279	0
2N140	46.0	58	0

The combined mean-time-to-failure of 10-element micromodules is 99,421 hours which is higher than the design value of 75,000 hours. Present parts are expected to do better.

REVIEW: The heavy emphasis on reliability is good to see. The program is still in a state of improvement, thus accomplishments are difficult to assess. While some mention is made of confidence levels early in the paper, the results which are presented do not seem to be at 90% confidence but are perhaps "expected values" or a similar "average." Mention is also made that infant mortality is presumed to be over in these tests, but no figures are given on it. Some of the results are from accelerated tests and probably suffer from their uncertainties. In spite of the problems the program seems to be in a state of "so far, so good."

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Why design for maintainability?

AUTHOR: Joseph G. Wohl, Dunlap and Associates, Inc., Stamford, Connecticut

SOURCE: 1961 IRE International Convention Record, Part 5, New York, New York, pp. 312-321, March, 1961

PURPOSE: To show that design for good maintainability is worthwhile.

ABSTRACT: This paper is limited to unscheduled down time (defined as the length of time, measured from the time of occurrence, that a device is unable to provide a specified level of performance). If an equipment has a mean time to failure of 50 hours, a duty cycle of 2/3, and an average down time of 15 hours, the unit is being serviced 20% of the time. A probability of 0.9 that at least 4 out of 5 of these devices will be operating cannot be met no matter how many technicians are available. If the mean down time is reduced to 10 hours, 1 technician for each set can keep up. If it is reduced to 7.5 hours, only 2 technicians are required. A 25% reduction in down time causes a 60% reduction in personnel. Thus the overall return on extra engineering time can be enormous.

Various combinations of reliability and maintainability will give the same system availability. There may be some constraints on the permissible values of reliability and maintainability, but there will still be a region where trade-offs are possible. Thus a manufacturer can balance these two for minimum system cost. The cost rises sharply as either one is brought toward zero. It will usually be much cheaper to increase availability by increasing maintainability rather than reliability.

Very little work has been done to find out the relationships of down time to design factors. Two studies have shown that good design can reduce down time. Much work needs to be done to find means of measuring and predicting the parameters that are involved.

REVIEW: The design of equipment for easy service and minimum down time when repair is necessary is certainly a good idea. One factor that seems to be omitted in the discussion of trade-off of reliability vs. maintainability is the cost of servicing. The customer probably would want to put some price penalty on equipment that sacrificed reliability for ease of service. It is difficult to see that, in the overall view, unreliable equipment--easily serviced, is as good as reliable equipment which may be difficult to repair. The many hidden social costs of repair such as teaching expense and loss of productivity of those engaged in service should surely be considered.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Trans-Canada's experience with the Rolls-Royce Conway

AUTHORS: J. T. Dyment and J. J. Eden, Trans-Canada Air Lines

SOURCE: SAE Journal, vol. 69, July, 1961, pp. 44-48

PURPOSE: To describe the steps taken to monitor the performance of the engine and to predict maintenance intervals.

ABSTRACT: The Rolls-Royce Conway turbine engine is used on TCA's DC-8 jet aircraft. Two programs help improve the engines' reliability: (1) equipment for preventive failure analysis and recognition of problems at the start, (2) planned increases in the engine overhaul periods and in-service life of engine components to the maximum possible consistent with safety. The vibration level is continuously monitored (one test equipment has over 2000 hours without failure). The normal level of 0.001 to 0.002 inches is positively exceeded when a blade fails and even when a bearing fails. This is also used to check the engines after overhaul; three were rejected in this test and were all found to have balancing errors. The maintenance people also need positive checkouts to see if in-flight warnings are true or false. For engine overheating, a zinc pellet is used; if the engine has truly overheated, the pellet melts. Metal detecting plugs can be installed in engine oil scavenge lines or filter to show up incipient bearing failures. Individual filter pressure checks have not proved to be reliable indicators of the engine state; so the metals deposited in the filters are checked and recorded. This has proved out very well in practice. Fuel consumption of each engine is also recorded. At the moment, no way is known to improve the performances of all engines to make them equal to the best, nor are the causes of the poor performance of some engines known.

Trial engines are run for 100 hours more than the overhaul life for which approval is sought. In this case, small samples are considered to be valid. Actually, the test is not stopped there, but is continued for further valuable information. By this means, 1500 hours has been reached on the trial engines and 2000 hours overhaul life is the next objective.

REVIEW: This paper is on the subject of mechanical reliability and should be of use to those who are concerned in this area. The problem of small sample sizes is very much in evidence for the reliability testing.

REFERENCE: SAE paper #345C from which the article was prepared.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Basic statistical concepts of reliability

AUTHOR: Frank M. Gryna, Jr., The Martin Company, Baltimore 3, Maryland

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 41-50, January, 1961

PURPOSE: To present some concepts and definitions of reliability, failure rate, and frequency distributions to those new to the field.

ABSTRACT: The terms "reliability," "frequency distribution," "failure rate," and "mean time between failures" are defined and explored. The effects of components and redundancy on system reliability are discussed with comment on the validity of certain assumptions such as independence of component reliability. The product rule and the exponential formula are described and examples given. The evaluation of test data for reliability demonstration is considered in conjunction with confidence levels to obtain confidence limits.

REVIEW: This is a brief but generally well-written presentation for those unfamiliar with the problems of reliability. Most terms are well identified and defined and some half dozen specific examples are cited. A number of careful distinctions are made, e.g. between "mean time between failure" and "operating life" or "service life." The section on redundancy does not mention the assumptions implicit for the stated formula, such as perfect switching between redundant equipments, or that life of one redundant part is unaffected by the state of the other one.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Simple statistics applied to semiconductor processes

AUTHOR: Warren R. Clemens, Semiconductor Division, Hughes Aircraft Company, Newport Beach, California

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 103-110, January, 1961

PURPOSE: To describe some simple applications of advanced methods in statistics to the quality control of semiconductor processes.

ABSTRACT: Case histories are cited on the applications of chi-square tests to fusion differences, a 2-factor experiment using one qualitative and one quantitative factor, and a 2^3 factorial experiment. The compilation of an Experiment Error Catalog is briefly described and a successful application of a screening experiment using Modified Random Balance Design to an 8-factor, 2-level problem is discussed. Conclusions are cited for all of the examples.

REVIEW: No theory is developed or even explicitly stated, and little detail is offered in the examples. Value, if any, resides in the reporting of successful usage of certain statistical methods. The reader interested in learning about the details will have to look elsewhere.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability testing

AUTHOR: A. L. Floyd, Military Products Division, Hoffman Electronics Corporation, Los Angeles, California

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 134-143, January, 1961

PURPOSE: To introduce the basic theory of reliability testing particularly as applied to acceptance limits set forth by AGREE.

ABSTRACT: The conventional force of mortality (or hazard rate) is defined and analyzed. Whenever this force is a constant, the exponential law is obeyed. For single components and large unmaintained equipment, the force of mortality is high at the beginning, then drops to a much lower value. Later when the device begins to wear out, the force of mortality again rises. Each region is often approximated by a constant value. If the equipment is repaired, some parts enter the wearout region before others and are replaced. This causes the wearout region to be "bumpy" and not well defined.

In any test, the stresses determine the mortality force. These stresses are usually confined to those which accelerate mechanical or chemical changes. The AGREE report [1] has set four standard stress levels for equipment testing, L, M, H, and X (from laboratory service to extreme service). Accelerated testing is feasible if one or two factors are most important and if the failure modes do not change with the increased stress.

The statistical design of the test is done by conventional means. The sample size is determined by the allowable fraction defective of the population, the required confidence in the test decision (consumer's risk) and the number of defects allowed in the sample. The number of total accumulated operating hours is also fixed. A producer's risk can be assumed and a sequential test run. In this case, if the equipment is very good or very bad, it is usually possible to shorten the test.

An example is given of reliability improvement achieved by analyzing the failure causes and eliminating them after each test. More complete references for the statistical design of these tests are also given.

REFERENCE: [1] Reliability of Military Electronic Equipment, Advisory Group on Reliability of Electronic Equipment, Office of the Assistant Secretary of Defense (Research and Engineering), 4 June, 1957

REVIEW: This is an adequate introductory paper to the subject of reliability testing. It is rather abbreviated, especially the section on statistical design, but more complete references are given.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Manufacturing's contribution to reliability

AUTHOR: Thomas A. Budne, Statistical Engineering Consultant, Great Neck, New York

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 144-148, January, 1961

PURPOSE: To present ideas which will help to optimize a manufacturing department's procedures.

ABSTRACT: Maximum reliability requires optimized performance of all functions. This paper limits itself to manufacturing processes. Scrap and rejects are the visible evidence that causes for unreliability exist. If each department is charged with the costs of its avoidable mistakes, it will try to optimize its performance, and improved reliability will result. In any problem, the important areas are only a very few possible ones; initial effort should be to find these few important ones and all further effort should be devoted only to them. Two examples are given. The feedback to provide incentive for optimizing is effective cost accounting (charging all avoidable errors to the responsible department--even though it may not be a conventional charge).

REVIEW: The paper is more limited than the title implies. The necessary interaction between engineering and manufacturing is mentioned only briefly. Basically the thesis is that if the "economic screws" are tightened a little, people will optimize their procedures. This may be true, but the current consensus is that this is in no way sufficient to assure reliability in the final product. It may also be noted that one can optimize with respect to many things besides reliability.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Field reliability

AUTHOR: H. Bayer, Douglas Aircraft Company, Inc., El Segundo, California

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 163-168, January, 1961

PURPOSE: To describe the continuing field effort necessary to have the end product meet design goals and predictions.

ABSTRACT: Field reliability has three parts: observation, verification, and reporting. These must be supplemented by corrective action in the plant. As an example, five charts show the improvement due to field work in a system and its four subsystems as a function of time. An illustration is used which shows the need for high quality field men: A part which arrives in the field has been damaged in shipping; incorrect or insufficient reporting may set off corrective efforts in entirely wrong directions. For example, the plant might try to redesign the part to make it more rugged, when all that was necessary was better packaging.

REVIEW: This paper summarizes some of the aspects of field reliability. It has good emphasis on the need for well-trained, active field reliability engineers and for home plant personnel's listening to their requests for action on field reports. Better reliability specifications, more attention during the design period to reliability, and really rugged acceptance testing such as specified in the AGREE Report will decrease the load on field engineers, who now carry a major load in many circumstances. An implicit thread running through the paper is that equipment should be more fool-proof; one must design, build and package so that people who do not do the right thing will cause little or no damage.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Intra-corporation reliability coordination

AUTHOR: Walter J. Picker, Reliability Manager, Librascope Division, General Precision, Inc., Glendale 1, California

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 182-183, January, 1961

PURPOSE: To summarize some internal experience with a reliability group.

ABSTRACT: Within large, multi-divisional corporations, a significant amount of reliability knowledge exists that can be given wide usage to increase reliability capability and decrease duplication of effort. This paper describes the activities, goals, and initial performance of a committee recently formed to coordinate reliability operations among the four divisions of General Precision, Incorporated, a subsidiary of General Precision Equipment Corporation of New York. This paper also reviews the committee's successes and failures and may provide some guidelines for other large corporations wishing to fully utilize their own reliability activities.

In conclusion, it can be stated that the GPI Reliability Committee has "paid its own way" by successfully integrating the results of reliability activities at the four major divisions. Although some of the original discussions of the committee were tedious and sometimes unproductive, the overall program results have definitely been worth the time and costs involved. (Author)

REVIEW: This is a refreshingly brief and somewhat frank summary of an attempt to coordinate the reliability effort within a multi-division corporation. The paper contains no design information.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Policies for reliability organization in a multi-product division company

AUTHOR: John M. Wuerth, Chief Reliability Advisor, Autonetics, a Division of North American Aviation, Inc., Downey, California

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 184-188, January, 1961

PURPOSE: To show how a company, with several product divisions, coordinates its reliability effort.

ABSTRACT: This paper discusses fundamental considerations involved in the management problem of establishing an effective organization for reliability within the complex organizational framework of a Multi-Product Division Company. Basic principles are defined and explained. The application of these principles is also traced through a series of changes in the basic organizational structure of Autonetics to show how they have been applied to date in different ways to meet different organizational problems. It is the author's firm belief that the principles and concepts of reliability organization discussed in this paper can have wide application throughout industry. Although there are still problems to be solved, the application of these principles at Autonetics has already led to Autonetics' industrial leadership in the field of product reliability.

...The key to this approach is line management responsibility--supported by specialized individuals, or groups, placed throughout the entire organizational structure wherever they can prove most effective. (Author)

REVIEW: This paper discusses some of the top-management aspects of a reliability organization in a large company. The paper contains no design information.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: System analysis--non-linear estimation techniques

AUTHOR: Nathan Rosner, International Business Machines Corporation, Federal Systems Division, Kingston, New York

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 203-207, January, 1961

PURPOSE: To describe a mathematical model defining the early debugging phase of an electronic system.

ABSTRACT: Empirical studies have shown that after debugging phases are completed, the mean-time-to-failure of an electronic system remains relatively constant during the normal life of the equipment. This relatively constant failure rate after completion of the debugging phase gives reason to assume that during the early debugging phase the number of expected failures is a function of the constant failure rate (which is not time dependent) and the debugging failures (which are time dependent). The number of debugging failures (Y) remaining at any time is such that its rate of change with respect to time is negative and proportional to Y. The solution of the resulting differential equation yields Y as an exponential function of time, which may be integrated to give the cumulative amount of debugging failures removed at time t. The complete equation expressing the cumulative number of failures due to both the debugging failures and the constant failure rate is then readily obtained. For the estimation of the parameters in this equation, a non-linear estimation program is required. Such a program has been written, and its application to the evaluation of the early performance phase of an electronic system under development is demonstrated.

REVIEW: Design engineers working on the development of electronic systems may find the program described in this paper quite helpful. It could be a useful tool in determing mean-time-to-failure at an early stage in the development. As the author points out, it may also serve as a maintenance tool in determing the time required for the debugging phase.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improving system reliability

AUTHORS: K. M. Hall, Senior Engineer and R. H. McDonald, Development Engineer, Sylvania Systems Division, Reconnaissance Systems Laboratory, Mountain View, California

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 214-228, January, 1961

PURPOSE: To show how redundancy on a subsystem level can improve reliability if the subsystems are monitored.

ABSTRACT: While redundancy at the subsystem level is not usually practical on systems where weight and size are overriding factors, it is useful on many systems that do not have these limits. Redundancy without monitoring has little to offer in the case of a system made up of several identical subsystems. For example, if the mean-time-to failure is 100 hours and the expected repair time is 2 hours (both times are exponentially distributed), 8 subsystems without monitoring are equivalent in mean life to 2 subsystems monitored every 60 hours. Two models, plus four special cases of one of them, are analyzed for mean time to failure and availability. The exponential distribution is assumed for both life and repair times. The models without monitoring clearly show that the improvements due to redundancy are not very great. The most general model assumes monitoring at equal intervals of time and an expected value for repair. With three parameters to vary and two answers to find, only a few examples of results can be given. An application is discussed which involved a low-reliability receiver, high reliability requirements, and not enough time to redesign and prove the receiver. The solution was to slightly change the receiver for a mean repair time of 24 minutes and to use two receivers. Each receiver was to be checked once a day.

Several of the more complicated equations are derived in the appendix.

REVIEW: This paper clearly shows the advantages of monitoring the subsystems. The assumptions used are clearly spelled out and no difficulty should be experienced in following the derivations. An extension of this work might be to see how sensitive the results are to the "exponential" assumptions.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Accelerated reliability testing

AUTHORS: Anthony D. Pettinato, Rome Air Development Center and Richard L. McLaughlin, Radio Corporation of America, Rome, New York

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 241-252, January, 1961

PURPOSE: To show that accelerated life testing is feasible for electronic equipment.

ABSTRACT: Military specifications now, in many cases, call for a demonstration of reliability, e.g. MIL-R-26474, "Reliability Requirements for Production", and MIL-R-27070, "Reliability Requirements for Ground Electronic Equipment". The testing program involved in this demonstration takes time and money. To find a way to reduce the time and expenditure normally required for these tests, Rome Air Development Center and RCA Service Company, A Division of Radio Corporation of America, joined together in development of techniques of accelerated reliability testing.

The technique chosen was that of increased room ambient temperature. By increasing the temperature to 70°C. (158°F.) in the case of the equipment with vacuum tubes and 60°C. (140°F.) in the case of the equipment with transistors, it was possible to achieve an average acceleration factor of 2.3 over the normal. This was established by actual tests, both normal and accelerated, on five single channel communications equipments, AN/GRR-7/GRT-3, three multi-channel communications equipments, AN/GRC-27 and ten transistorized AVR-200 marker beacon receiver equipments.

It would be most logical if, as the next step, the line voltage were to be increased; although it might prove difficult to get correlation between the results at normal line voltage and increased line voltage. Then the combination of the two, increased line voltage and increased temperature could be applied. (Authors)

REVIEW: The 90% confidence limits on the acceleration factor of 2.3 are quite broad--1.4 to 3.6. Very likely this would be due to different effects of temperature on components rather than to small sizes. Accelerated testing in special cases may be satisfactory and certainly will always be used in the effort to find and eliminate failure mechanisms. But extrapolation of life to normal performance is rather risky--and the risks are usually unknown.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design techniques evaluation for reliability

AUTHORS: Robert Warr, John Bilinski, and John Olsson, General Electric Company, Advanced Electronics Center, Cornell University Industry Research Park, Ithaca, New York

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 283-291, January, 1961

PURPOSE: To describe a reliability evaluation method which uses ratings of design techniques.

ABSTRACT: This method supplements the usual ones of Failure Rate Prediction and Test Evaluation. Rating forms, for use by experts in any technical area, have been prepared. On these forms, the design techniques are evaluated, rather than the design itself. The Rater must have access to information such as specifications and circuit development and test information, in the following design areas: electrical, mechanical, thermal, shock and vibration and miscellaneous environments. Rather than one single rating, a profile chart is used with a rating for each design area.

In addition to reliability, this technique can also be used to evaluate maintainability, longevity, safety, and fail-safeness. It has been validated through preliminary tests on a variety of equipments and with many Raters. It can be used in systematic design reviews, and in diagnosis and improvement of equipment reliability. The forms are shown in full at the end of the article.

REVIEW: While the early part of the article stresses evaluation of design techniques, the system seems generally to concentrate on the design itself. Anything that focuses attention on the design and design methods should serve a useful purpose. This program seems to be similar to many other reliability-emphasis programs.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Redundancy considerations in space and satellite systems

AUTHORS: L. A. Aroian, Space Technology Laboratories, Los Angeles 45, California and R. H. Myers, Hughes Aircraft Company, Culver City, California

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 292-301, January, 1961

PURPOSE: To derive some survival functions for several failure distributions with sequential redundancy and to summarize some of the engineering aspects of redundancy.

ABSTRACT: A 40,000 hour mean life requirement for satellites and a 200 hour mean life of actual systems (non-redundant) suggest the need for redundancy, since part and circuit improvement cannot bridge the gap soon enough. Sequential redundancy is preferable to the functional type. The survival formulas are derived for these distributions (all sequential): one, two, three, and "r" exponentials; one, two and "n" normals; one exponential followed by a normal; one Weibull and a special case of two Weibulls; one and two Chi-Squares; and some generalizations of four or more items in sequence. Degradation due to disuse is briefly discussed.

Twelve factors favor sequential redundancy over the functional type: (1) manufacturing defects are more easily detected, (2) there are fewer chances of degradation failures, (3) stresses on survivors do not increase, (4) part temperatures are lower, (5) design time and costs are lower, (6) failures tend to be more independent, (7) the extension of life is much longer when one short-lived part causes failure, (8) the number of redundant units is flexible, (9) life testing and consequent improvements are easier, (10) less power is consumed, (11) no failure mode analysis is necessary for the redundancy, (12) protection is provided against degradation factors as well as catastrophic failures. Five factors favoring functional over sequential redundancy are: (1) no "perfect" switches are required, (2) parts do not degrade due to non-use, (3) resists jamming better, (4) no down time after a failure, and (5) no data is lost at failure. It is worth emphasizing that redundancy is not a cure-all; it should be used after further part and circuit improvements are no longer feasible.

REVIEW: The paper is largely a mathematical derivation of several survival functions. Except that they concern redundancy, they are not related to the engineering summary. The section on the distributions has some errors; for example, factors of 1/2 are missing in the χ^2 density functions quoted. However, a compensating error of integration gives the correct result. No proof is given of the superiority of sequential over functional redundancy. The paper is useful chiefly as an introduction to the subject.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design review - the why and the how

AUTHORS: Rudolph S. Cazanjian, Sylvania Electronic Systems, Mountain View, California and Richard M. Jacobs, Sylvania Electronic Systems, Waltham, Massachusetts

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 344-350, January, 1961

PURPOSE: To summarize the need for and the types of design reviews.

ABSTRACT: Many specialists work on the design and the development of large complex systems, and coordination of their effort is difficult. The design review is an attempt to solve this problem. There are many different approaches, such as the "independent review," "the verbal review," and the "checklist review." The cost savings of these programs are extremely difficult to calculate. Each program is summarized and four important points are made, viz. design reviews must 1) have effective communication 2) be scheduled properly 3) be to the point 4) be adequately funded and recorded. The three approaches are expanded into eight examples related to different companies. All are rated as successful by the users, but the critical reviewer has his doubts. The final recommendations for design review are presented. These encompass first the written checklist, then a verbal review with responsibility resting in the original engineering group. Other reviews follow as the system develops. Two figures give explicit examples.

REVIEW: This is an expository paper on design reviews. It seems to accomplish the aims of the title. It does not, however, supply detailed information. As the authors indicate, this is a rather controversial subject, and each organization must work out the program best suited to its own needs.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The value of design prediction?

AUTHOR: Robert T. Williams, ARINC Research Corporation, Washington, D. C.

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 375-379, January, 1961

PURPOSE: To show that reliability predictions are worthwhile during design and that they should be continued throughout the development.

ABSTRACT: Reliability prediction must be a continuing process from system concept through production if it is to be a valuable design tool. It has been emphasized that the designer should participate in the prediction effort; yet he does not have readily available the background, techniques, facilities, and data which he needs to accomplish meaningful predictions. It is the task of the reliability engineer to be ever ready to provide the information and data requested by the designer. Unless the reliability engineer can give guidance, supply data, provide techniques, and accurately interpret prediction results, predictions will not be fully utilized, and he will not be meeting the challenge of his position. (Author)

REVIEW: This is an introductory paper of use to the beginner or skeptic. An attempt is made to answer some objections to design prediction and to list some of its benefits.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The measurability of the reliability of an expensive guided missile type

AUTHOR: E. G. Pieruschka, Lockheed Aircraft Corporation, Missiles and Space Division, Sunnyvale, California

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 394-406, January, 1961

PURPOSE: To discuss some basic concepts regarding the measurability of reliability.

ABSTRACT: The statistical determination of the reliability of an equipment requires a large number of tests. When only a few units are available, as in the case of expensive weapons, the reliability can be given only within a rather broad range.

This paper discusses some basic concepts regarding the measurability of reliability. Topics considered are: degree of confidence in reliability computed from a small sample, statistical assurance that there is a difference between two reliabilities, computation of system reliability when given test data on subsystems, measurability of the increase in reliability during the developmental phase, and assurance of a contractually required reliability.

REVIEW: This paper is a realistic discussion of the problem of measuring reliability when only a relatively small amount of test data is available. Since the problem is of rather widespread occurrence where complex systems are involved, the paper would be worthwhile reading for those concerned with measuring the reliability of such systems.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Optimum checking procedures

AUTHORS: Richard E. Barlow*, Larry C. Hunter** and Frank Proschan, Sylvania Electronic Defense Laboratories (*Now with the Institute for Defense Analyses, Princeton University, Princeton, New Jersey; ** Now with General Telephone Laboratories, Menlo Park, California)

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 485-495, January, 1961

PURPOSE: To determine optimum checking procedures for the intermittent checking of articles with known life distributions.

ABSTRACT: A system is to be tested or checked according to some schedule until it is discovered through checking that the system has failed. Failure is assumed known only after a checking operation. Each check will entail a certain cost. Likewise, the elapsed time between system failure and discovery by a system check will entail another cost per unit elapsed time. Two types of checking procedures are analyzed and compared: (a) periodic checking procedures, in which checks are made independently of the time the system has been operating, and (b) sequential checking procedures, in which the checking schedule may vary with the time the system has been operating. The minimum cost checking procedures are characterized and examples are worked out to illustrate the general formulas derived. A second problem considered is that of obtaining an optimum sequential policy for systems which tend toward failure in stages, each stage being distinguishable. The optimum procedure is obtained by applying a dynamic programming approach to an appropriate Markov process. (Authors)

REVIEW: This paper treats the problem of obtaining optimum procedures for the checking of a system at intervals until the system fails. The assumption made is that each check costs a fixed amount and the time between system failure and discovery of the failure (by a check) involves a cost which is proportional to the length of that time. The results obtained should be useful in providing a guide to the best checking procedure in cases where the assumptions above are appropriate (and it is certainly possible to concieve of situations for which they will be appropriate, even though they may not be common situations). The mathematical development is neat throughout and a number of helpful practical examples are included.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An analog approach to reliable transistor circuits

AUTHOR: H. T. Gruber, Battelle Memorial Institute, Columbus, Ohio

SOURCE: Electromechanical Design, vol. 5, October, 1961, pp. 40-46

This paper is virtually the same as the one covered in Abstract and Review Serial Number 21, although no mention is made of previous publication.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the meaning of quantified maintainability

AUTHOR: Nicholas Maroulis, Light Military Electronics Department, General Electric Company, Utica, New York

SOURCE: 12 pp., presented at the Western Electronic Show and Convention (WESCON), San Francisco, California, August, 1961

PURPOSE: To analyze maintenance in quantitative terms.

ABSTRACT: The four basic functions performed within a maintenance system are sampling, comparison, interpretation, and action. The goal of the system is to assure combat readiness of the equipment. The first step is to develop a maintenance plan: who tests it, how, when, and where. The test-logic specifications must define each property of each of the measurements. The sum of these specifications is used to develop the support equipment and procedures. Personnel requirements are generated by task analysis, grouping of tasks and identification of the skills necessary for each group. Using all this information plus the system properties, a maintenance and repair-operations analysis is made to formulate a detailed maintenance plan. The plan includes items such as tools, spare parts, handbooks and preventive maintenance. Numerical maintainability may now be thought of as a measure of the quality of the proposed plan (it should be distinguished from performance and reliability). Mean down time is the measure of maintainability. The total down time includes items beginning with consultations with the equipment operator to filling out the final forms. Some of these times are under control of the designer, and tests have shown that by proper attention to layout, coding, etc., some repair times can be materially reduced. An analysis of the system can now be made using queuing theory, Markov chains, information theory or regression analysis. The first and last are perhaps the more successful.

The PERT/PEP approach uses a flow diagram of the scheduling. It shows the times and interrelationships of the various sub-efforts in detail. The times entered on this diagram are the raw material for the final expected-time-to-repair table that can be made.

REVIEW: Of particular importance to design engineers is the idea that they can influence the repair ease of a system by proper design, and, as the author indicates, more knowledge is needed in this area. The paper is a general one and would be considered theoretical in that it presents a possible approach to the systematic quantitative treatment of maintainability.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Pendulum restrains motion to measure separation reliability

AUTHOR: Edward W. Schrader, Western Editor

SOURCE: Design News, vol. 16, October 13, 1961, pp. 16-17

PURPOSE: To show that the amount of reliability testing has been reduced in one case by the design and use of a special machine.

ABSTRACT: Go/no-go tests of an explosive separation system would require more than 60,000 shots to obtain a satisfactory reliability figure with a 95 percent confidence level. To overcome this high cost of testing, separation system designers developed a pendulum test to measure the available force margin.

By measuring the degree of success of each shot, and by applying statistical methods of reliability to these results, the number of shots required to obtain a 99.995 percent reliability at a 95 percent confidence level may be reduced to the order to 200 shots.

The motion of a pendulum is inherently restrictive; from rest it moves in only one direction. Therefore, the work the pendulum acquires in the form of kinetic energy may be measured.

Margin is defined as:

Margin = (Pressure energy)/(Loss energy) - 1

or Margin = (Pressure energy)/(Pressure energy-acceleration energy) - 1.

Instead of energy, margins are calculated from the impulse ratios (integral of the force-time relation), which can be measured by a planimeter integration of Polaroid photographs; for the particular nut design, the impulse margin shows a 1:1 correspondence with the energy margin. Other nut designs require that a comparison be established between the energy and the impulse margins so the more easily obtained impulse margins may be used for the energy margins.

The pendulum method for measuring nut separation is a design development of the Hi-Shear Corp., Torrance, Calif. (Author's entire article)

REVIEW: This article contains actual reliability numbers on a one-shot mechanical component and is noteworthy on this account.

In the attempt to reduce the amount of testing, a mathematical distribution of the Margin (probably the normal distribution) must have been assumed, explicitly or implicitly. The assumed distribution is called a model of the process. The parameters of this model are then estimated from the data and probability statements are made

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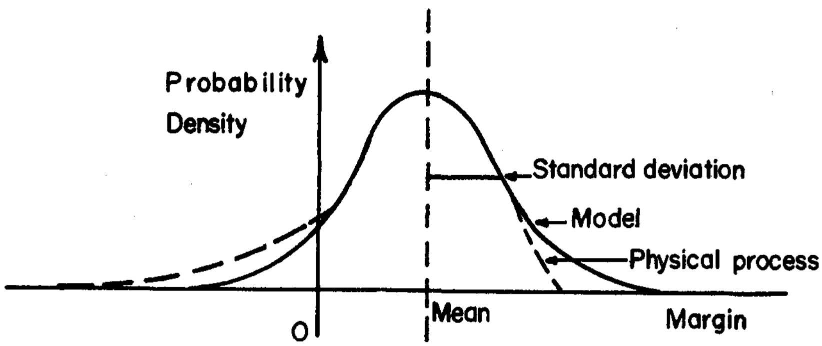
about the likelihood of having excess Margin. It is essential to realize that these probability statements apply only to the model, not necessarily to the physical situation. Any prediction about the amount of testing to achieve a desired result likewise applies only to the model.

A reliability of 99.995% = $1 - 5 \times 10^{-5}$ is mentioned in the article. This is away out on one of the tails of the distribution and it is very probable that an enormous amount of testing would have to be done to assure that the model fits the physical situation, as closely as desired, in this extreme-tail region. Again, it should be emphasized that even though this calculation is easy to make for the model (just by using the proper tables), the result may not have any bearing at all on the actual case at hand. The figure below shows an example of how the physical process and the model might differ at the tails, yet be rather close in the region of ordinary use. It is very difficult to test for this lack of correspondence in the tails.



A question can be raised about the confidence level and the reliability. For example, is there any point in estimating a fraction defective of 0.005% with a 5% chance of being wrong (95% confidence)? The fraction of the time that one is wrong in such cases could in the long run tend to raise the estimated fraction defective and make a very low figure rather meaningless. In general, it would seem that the estimated fraction defective and the chance of being wrong should be within at least a factor of 10 of each other.

More information on the model and amount of testing could probably be obtained from the Hi-Shear Corporation.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Calculating "worst-case" transistor leakage current

AUTHOR: E. D. Peterson, Military Electronics Division, Motorola, Inc., Phoenix, Arizona

SOURCE: Electronics, vol. 34, October 6, 1961, pp. 74-76

PURPOSE: To show how to calculate the maximum I_{CBO} at operating conditions.

ABSTRACT: The calculation of the total leakage current in the collector-base diode junction of a transistor (I_{CBO}) involves determining the highest junction temperature and the leakage currents contributed by the thermal and surface components. The principles stated here will also apply to emitter-base leakage (I_{EBO}) and the collector-emitter leakage (base open, emitter and collector biased normally; I_{ECO}). An explanation of I_{ECO} is given. The specifications usually list the leakage at 25°C and, sometimes, at several voltages. Since the thermal component is independent of voltage and the surface component is ohmic, the two portions can be separated if the leakage is given at two voltage levels. The thermal component will increase at the rule-of-thumb rate (double for each 10°C). The temperature dependence of the surface component is hard to estimate, but it can pessimistically be assumed to be 1/2 that of the thermal part. Since the voltage and temperature dependence of both parts are known, the I_{CBO} can be calculated at the operating conditions. This will involve estimating the junction temperature from the transistor ambient temperature and thermal resistance of the junction. The leakage will undoubtedly increase with usage. If the true factor is not known, an increase of at least 40% should be assumed.

This leakage current must be compensated even under worst case conditions of voltage and part parameters. An example is given which illustrates the various points made in the article.

REVIEW: This paper will help designers understand some of the problems connected with transistor leakage. The use of maximum ratings to find the two components is not rigorous since there is no guarantee that any of the individual transistors behave that way. Some may have large fractions of either the temperature or surface leakage and still meet the specifications. The extrapolation to other conditions may then have serious errors. It is probably best to rely only on those parameters which are part of the specifications and which the maker is forced to hold. The next best arrangement is probably to try and get the additional data from the maker--if he is willing to give it. If he is not, it would be wise to count on considerable fluctuations in the unspecified parameters.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: What price reliability?

AUTHOR: John E. Hickey, Jr., Associate Editor

SOURCE: Electronic Industries, vol. 20, September, 1961, pp. 142-156

PURPOSE: To present an overall view of the problems associated with reliability.

ABSTRACT: The responsibilities for the procurement and production of reliable electronic equipment lie with the legislative branch of the federal government, the military, and the individual manufacturers. The problems which arise may be classified roughly as in the list below, which essentially forms an outline of the paper.

- Congress
  - The low bid philosophy
  - Reliability vs. maintenance costs
  - Few-of-a-kind systems
  - Pushing the state-of-the-art
  - Usurping patent rights
  - Work in depressed areas
  - Work for depressed companies

- Military
  - Relegated a middleman role
  - Contract writing
  - Contractor penalties and incentives
  - Contract awarding
  - Required level of reliability
  - Planning and scheduling

- Manufacturer
  - Honest bidding
  - Organizing for reliability
  - Management's view
  - Employee disciplines
  - The designer's role
  - Failure recurrence
  - About vendors
  - Inspection and testing

REVIEW: This paper presents, in readable fashion, the current problems associated with reliability procurement and production, in particular those related to military electronic equipment. The information presented is non-technical in scope and should be of interest to those desiring a first picture or general review.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Profiles in failure rate vs. applications

AUTHOR: R. E. Pratt, Semiconductor Division, Raytheon Company, Newton, Massachusetts

SOURCE: the solid state journal, vol. 2, August, 1961, pp. 30-35

PURPOSE: To present a method for analyzing and presenting life test data in a manner useful to circuit designers.

ABSTRACT: The usual lot acceptance life test information on semiconductor devices is not adequate for many circuit design problems in which a designer is faced with meeting certain reliability requirements. What is actually needed is a life test program that is specifically designed to obtain engineering information. Besides the failure rate for a specific set of conditions and end points, the designer must know how failure rates vary as the life condition and the definition of failure are varied. Some of the questions which a life test program should answer are:

1. How important is derating junction temperature?

2. Is it more valuable to derate breakdown voltage 20 per cent or leakage current 100 per cent?

3. How much increase in reliability can be expected if design end-of-life for h_{FE} is changed from 90 per cent of initial lower limit to 70 per cent?

4. If designing wider end-of-life tolerance is necessary, which characteristic will produce the largest improvement for the least re-design work?

5. Do storage and operating life tests give compatible results?

This paper describes a life test program designed to generate information to provide answers to these questions, with particular emphasis on the analysis and presentation of the resulting data. The program is currently being operated in the Semiconductor Division of the Raytheon Company, and the results are being published as the analyses are completed.

REVIEW: This paper and the program which it describes will undoubtedly be of interest to design engineers involved with semiconductor devices. The material is clearly presented and illustrated with hypothetical data closely approximating actual experience.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the importance of operating life tests as compared to storage tests of transistors

AUTHOR: C. H. Zierdt, Jr., Semiconductor Products Department, General Electric Company, Syracuse, New York

SOURCE: the solid state journal, vol. 2, September, 1961, pp. 21-27

PURPOSE: To present evidence that higher failure rates may be produced and different failure mechanisms exhibited by transistors subjected to operating life tests as compared to storage tests.

ABSTRACT: The introduction of "gettering" elements and process improvements, in recent years, has resulted in production of transistors of such quality that high-temperature storage no longer accelerates failures to a rate high enough to yield useful information about lot-to-lot quality variations within a reasonable period.

Data are presented on groups of PNP and NPN germanium alloy and NPN silicon grown junction transistors tested for periods up to 10,000 hours. In all cases considered, the junction temperatures reached during the "on" portion of the cycled operating test were always lower than during the corresponding storage tests. The operating tests consisted of periods of 50 minutes on and 10 minutes off; the collector and emitter voltages were removed and applied simultaneously.

The cycled operating tests resulted in a higher failure rate than the corresponding storage tests. Analysis of the failure mechanisms point out the effects of collector voltage on silicon grown junction transistors and of emitter current on PNP germanium alloy transistors, which would not be discovered by high-temperature storage tests.

From the data presented, the author draws the following conclusions:

1. High-temperature storage testing is not the best failure-rate-accelerating condition for the transistor types studied, within a 0-10,000 hour period.

2. High-temperature storage testing does not accelerate the same failure mechanisms as do various operating and bias-condition tests. It may in fact, tend to mask certain failure mechanisms as a result of "annealing" effects.

3. Operating life tests induce several failure mechanisms simultaneously.

4. The failure mechanisms induced by operating or bias-condition life tests include many which contribute to "early failure" of transistors, at least in the 0-10,000 hour period.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

5. Operating life tests run at sufficiently high levels accelerate failure due to certain failure mechanisms, in the 0-1000 hour period.

6. Some transistor types are peculiarly susceptible to certain failure mechanisms not found in other types.

7. Complete study of a transistor type, including power-dissipating (cycled and continuous), bias-condition, and storage tests, is required to ascertain which tests will control the failure mechanisms peculiar to the type. It is also highly probable that, because of processing differences, the same complete study is required for each different manufacturer of the same transistor type, for high-reliability requirements (both the applicable type of test and the applicable stress level for given acceleration may differ between manufacturers).

REVIEW: The material presented is very timely and is summed up quite well in the conclusions. Publisher permitting, it would have been desirable to have the sections on "results of operating tests" and "failure mechanisms" expanded somewhat.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the estimation of system reliability

AUTHOR: David Rubinstein, General Electric Company, Light Military Electronics Department, Advanced Electronics Center, Ithaca, New York

SOURCE: Proceedings National Aerospace Electronics Conference, Dayton, Ohio, pp. 262-266, May, 1961

PURPOSE: To discuss the inadequacy of maximum likelihood estimation of the reliability of systems on the basis of life tests performed on their components.

ABSTRACT: It is assumed that the components fail independently according to the exponential failure law in both system operation and in life tests. The system reliability, R, can be approximated by exp(-P) where P is a polynomial in λ_i, i = 1, 2, ..., n, and λ_i is the failure rate of the i th component. The system reliability can be estimated by estimating P and then obtaining a point or confidence interval estimate of the reliability. The difficulties that arise in estimating P depend on the mode of testing. Two modes of testing are considered, namely: (1) testing with replacement or testing each component for a specified time T no matter how many failures occur, and (2) each of a fixed number of samples is tested until it fails.

It is shown that for both modes of testing the maximum likelihood estimates of P are biased and that poor estimates of system reliability may result from using these estimates. Improved estimates of system reliability are obtained if the maximum likelihood estimators of P are corrected for bias. For the second mode of testing it is necessary to test at least 2k + 1 samples to obtain good estimates of λ^k. The variances of various estimates are given. They are polynomials and can be estimated by unbiased estimates.

Approximate confidence limits for P are obtained by estimating the variance of the estimate of P and using the normal approximation. Because the variance of the estimate of P involves the unknown λ_i, i = 1, 2, ..., n, a procedure is given which should improve the estimate of the confidence limits. Having obtained a confidence interval estimate of P one readily obtains the corresponding interval for R.

REVIEW: This paper provides results which should be of interest to engineers and statisticians who wish to estimate the reliability of a complex system. The method for obtaining an approximate confidence interval estimate of P is very interesting. The user of the methods presented should carefully consider the approximations used in estimating the system reliability, the method of testing, and the underlying failure distribution.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability--space-age requirement

AUTHOR: D. S. Halacy, Motorola Semiconductor Products Inc.

SOURCE: Electronics World, vol. 66, December, 1961, pp. 38-39

PURPOSE: To clarify the term "reliability" by definitions and illustrations.

ABSTRACT: Reliability is now a part of the technician's and engineer's vocabulary and we have reached the technological point where as much time is often spent to improve reliability as is spent to produce the equipment. The reliability technician and engineer have already developed a language of their own. This article attempts to clarify the term "reliability" by definitions and examples. Topics discussed include: definition of reliability, product rule, need for reliability, failure rate, confidence level, and quality control.

REVIEW: This paper is quite elementary and contains no technical information of which the reliability engineer will be unaware. The principal point which is brought out is that, given the product rule, individual component reliabilities must be extremely high in order to meet reasonable system reliability goals.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Quantized probability design

AUTHOR: Richard B. Hurley, Advisory Engineer, IBM Products Division, San Jose, California

SOURCE: Electronic Equipment Engineering, vol. 9, September, 1961, pp. 51-54 and October, 1961, pp. 65-68

PURPOSE: To present a method of worst-case circuit design that is less conservative than most others in use.

ABSTRACT: Electronic circuits which can tolerate worst-case component changes tend to have less application efficiency than those designed for maximum performance. In large systems, a balance must be struck between failures due to component drift and those due to catastrophic part failure. An ideal situation would be when (1) all component parameters have specified end-of-life tolerance limits and these limits are chosen so that all components have the same average life; and (2) all circuits are designed to have the same average life span as the components. The method shown here attempts to do this. The three steps are: (A) choose tolerance weights on the basis of rough statistical criteria and engineering judgment; (B) perform a worst-case design using the weighted tolerances; and (C) statistically analyze the resulting design to see if it is satisfactory.

Some statistical formulae are derived under the following assumptions: (1) all parameter tolerances have the same meaning, and (2) a resulting circuit performance has the same kind of distribution with the same probability of failure as in (1). The normal distribution is a common one and has other desirable properties. When the performance equation is non-linear, a Taylor's series expansion about the nominal values can often be used to linearize it (all higher order terms must be negligible). Three common classifications of tolerances are

(1) ZT = zero tolerance. Parameters at NOM or nominal values.

(2) IT = initial or purchase tolerance. This is designated as IWC or initial worst case.

(3) AT = absolute or end-of-life tolerance. This is designated as AWC or absolute worst case.

One design method is AWC for everything. These circuits tend to have poor application efficiency due to over-design. Another is the Taylor criterion: the circuit must meet its performance specifications with all components at IWC and with any one component at AWC. This has better efficiency and is easy to apply. The method offered here has still better efficiency. An example is given of several series resistors, the total resistance being the measure of performance.

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R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

AWC, IWC and uniform statistical probability are used to solve it. The AWC is very conservative and the IWC less so.

The rules of quantized probability design (QPD) constitute a less conservative worst case technique. They are: (1) single parameters exhibiting a first order effect on performance--use AWC; (2) single parameters having a second order effect or multiple parameters with first order effects--use IWC; (3) single parameters with third order effects or multiple parameters with second order effects--use NOM values. Several rules are given for calculating these values from device specifications.

An example of a NOR circuit design with a fan-in of 3 and an NPN transistor is worked out for several methods. The conditions for having the circuit in the ON and OFF states are written down and then the equations (usually inequalities) are solved. The QPD result is statistically analyzed and shown to be satisfactory. When using QPD, the results should always be checked statistically.

REVIEW: This supplements other worst-case statistical design articles (See, for example, Abstracts and Reviews Serial Numbers 24, 35, and 58). It should be borne in mind that this paper describes a method of analysis and design which may, or may not, be applicable to any real situation. For example, there is an implicit assumption that all parameter deviations are uncorrelated. In many physical situations where deviations occur with temperature or time, there are very definite trends and the analysis here would not apply. In the Taylor's series expansion, about the only way to determine the accuracy of the linear approximation is to evaluate the quadratic (and sometimes further) terms if the expression is at all complicated. The tabulation of the tails of the normal distribution beyond $\pm$ 3 standard deviations can be misleading in that there is rarely evidence in any physical situation that a given distribution fits the normal one that closely.

In the design example the source of some of the numbers is not clear, e.g., the minimum UP signal of 5.88v. The supply voltage and its tolerance are not given until almost the end of the example. Some approximations are made implicitly, such as ignoring the collector loading ("on" condition) of the bases of the following stages. Other parameters are said to be of second order when it is not at all clear that they are, if maximum circuit performance is desired. If the design is to be checked statistically, it is not made clear why it could not have been done statistically in the first place.

Articles of this type are worthwhile in that they all contribute to a growing interest in, and knowledge of, reliable-circuit design. One of the most important parts of any design article is to spell out all of the assumptions that are made--and, of course, to have them fit the physical situation reasonably well.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Environmental requirements for semiconductors

AUTHOR: Karl Eklund, Director of Research, Radiation Dynamics, Inc., Westbury, New York

SOURCE: Electronic Equipment Engineering, vol. 9, October, 1961, pp. 57-60

PURPOSE: To review various environmental tests, especially those in Military Specifications.

ABSTRACT: The reason for environmental testing is to find out how long a device will function under adverse conditions. In general, some Military Specifications will be involved, but which ones? The basic ones for semiconductors are Mil-E-1 and Mil-T-19500. These are summarized in two tables. Another table lists the tests in Mil-STD-202A, Mil-E-5272 and in Mil-E-5400. Usually some judgment is necessary in picking the proper tests.

Another approach to reliability testing is comparative evaluation under given conditions. The stresses on several samples might be increased until the different specimens are sufficiently evaluated. Modifications of Military Specifications are very common where a manufacturer wants to emphasize a certain weak condition. Several examples are given.

It seems doubtful that standardization of environments can be accomplished in the near future.

REVIEW: This article is an interesting summary of some of the Military Specifications. One might hope that some kind of standardization is a little closer than the author thinks--perhaps in the form of many possible "standard" conditions.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Correlation studies between destructive and nondestructive tests of electronic components

AUTHOR: D. D. Seltzer, Chief, Quality Materials Laboratories, The Martin Company, Baltimore, Maryland

SOURCE: Nondestructive Testing, vol. 19, pp. 243-251, July-August, 1961

PURPOSE: To describe several case histories of successful use of nondestructive testing.

ABSTRACT: Nondestructive tests can best be applied when there is a correlation between them and destructive tests. The examples shown in the paper include primarily macro- and micro-examination. Items such as pyrotechnic components can be used only once and this makes it difficult to prove that they will act properly. Radiographs were taken of these before and after activation and in two perpendicular directions. They were able to reveal such things as: premature firing of the powder, breaking of wires during assembly, and proper seating of parts. Mercury wetted relays with an octal base had defective solder joints in the pins. The solder height inside the pin, determined by x rays, could be much less than that seen outside from the solder-dip. Other defects in this solder connection were also found and analyzed by x raying. Lead zirconate titanate ceramic cylinders (hollow) can have small invisible cracks which cause malfunction in operation. Three methods were successfully used for inspection here: fluorescent penetrants, ultrasonic reflections, and impedance measurements in the resonant region. Defective cylinders had erratic and lower impedance values near their resonances. An extensive analysis on the capillary flow of solder on stranded copper wire was carried out. Several soldering methods were compared, and the capillary flow measured. In addition, many samples were bend-fatigue tested. It was determined that the soldering methods producing the least capillary flow gave the longest fatigue life. The oxidation of silver plate gives a surface different from soft solder. Most producers now try to eliminate this oxidation, but many older parts still exist. Visual examination showed that heavily oxidized surfaces cannot be easily soldered even with activated fluxes, although the latter do help if the contamination is not too evident.

REVIEW: Nondestructive tests are very important in quality control work. By this means many poor processes and defects can be eliminated. The quality of the photographs in the paper is sufficiently poor, in general, to detract from it. Also, the author seems to be writing for those intimately acquainted with the problems and terminology. This results in a paper that is rather difficult to read and understand. An important omission in the optical micrometer discussion is that the apparent thickness must be divided by the index of refraction of the coating.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Maximizing electronic reliability

AUTHOR: Morris Halio, U. S. Army Transportation Materiel Command, St. Louis, Missouri

SOURCE: The Journal of the British Institution of Radio Engineers, vol. 21, pp. 121-128, February, 1961

PURPOSE: To make general recommendations for increasing electronic equipment reliability.

ABSTRACT: Reliability should be quantitatively incorporated in the planning stage and in all development and equipment contracts. During design and development each component should be analyzed for its strength vs. stresses imposed on it. The average values of these should be far enough apart so that the tails of the distributions will not overlap. (Lusser's safety margin is introduced here.) Standardized high reliability components are needed and there is some progress in this direction. The testing of components to failure is much better than testing complete equipments under operating conditions, because failure modes can be found and fixed. Universal components are generally not as good as special purpose ones if the production of the latter is great enough. The circuit designer should select parts with the highest inherent reliability and then design the system to allow for as great tolerances as possible. The equipment should be simple, easy to operate and easy to fix. Critical adjustments should be avoided. Good, reliable performance is better than excellent, unreliable behavior. Thermal and mechanical stresses should be minimized by careful analysis of these phases. Standardized proven circuits should be used where possible. During this period there should be frequent design reviews by experts in each field. Pilot production should be accompanied by environmental and marginal condition tests. During manufacture, automation and intensive quality control will help keep a high reliability. Quantity production should not be rushed before a good reliable design is achieved. The units should be properly packed to resist damage during shipment and storage. Proper maintenance facilities are essential and are not given enough consideration by the military.

REVIEW: This is an adequate introduction to the field of reliability. It is an elementary paper and contains no design information. Even though published in a British journal, the article is about practices in this country.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Component and valve reliability in domestic radio and television receivers

AUTHOR: D. W. Heightman, Technical Director, Radio Rentals Ltd., Wembley (England)

SOURCE: The Journal of the British Institution of Radio Engineers, vol. 21, pp. 401-407, May, 1961

PURPOSE: To present information on the reliability of television receivers.

ABSTRACT: The paper concentrates mainly on television receivers since they are more complex (thus more unreliable) than radios. Failure rates are higher in the first few months (2 to 2 1/2 failures per set per year) than after about 6 months (1 1/2 failures per set per year) although the failure rate of valves (tubes) seems to stay constant at about 1/2 failure per set per year. After about 2 years, wear-out increases the failure rate of the sets. The tuners are one of the main sources of trouble; oscillator stability and contact resistance in the switches are usually the causes. Improvements in valves have reduced the number of faults, especially in early life. The double valves have less than half the reliability of single ones. Valve pins and sockets can have poor mutual contact. The I.F. alignment problems would be solved by using stable fixed-tuned stages. Bad soldering and wiring faults account for 1/7 of the faulty receivers; printed circuits are cutting this number in half. Potentiometers may fail early due to poor assembly or later due to wearing of the carbon track. Carbon resistors are much better than the wire wound ones; the fine wire seems to break rather readily. Of capacitors, the electrolytics have a short life--presumably due to drying out; poor quality control can cause early failures. Low frequency inductors and transformers are generally good except where high voltages are concerned. Most loud speakers that are made properly give little trouble. Selenium rectifiers are much more satisfactory than valves.

Discussion by Mr. D. H. Busby. The main factors of reliability are the number of components and valves, the power losses and operating temperatures, adequate derating and use of circuits which allow component value variations. Derating is good, even at the expense of more components or valves. The valve failure rate is good; further improvements will be small and slow.

REVIEW: Some figures and charts are given which show actual failure rates. It is very interesting to see papers on the subject of commercial equipment reliability and to know that people are concerned about it. While there is little that is actually new, the paper is very worthwhile. See also Abstract and Review Serial Number 76.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Life characteristics of some typical semi-conductor devices

AUTHORS: R. Brewer and D. J. E. Richards, General Electric Company Ltd. Central Research Laboratories, Hirst Research Center, Wembley, England

SOURCE: The Journal of the British Institution of Radio Engineers, vol. 21, pp. 485-489, June, 1961

PURPOSE: To outline some of the available transistor life test data.

ABSTRACT: Some long term life data are now available on a few transistors, both from laboratory tests and the field. Deterioration as well as inoperative (catastrophic) failures are included. One problem is that it is very dangerous to generalize from the results of one type to some or all others. In one batch of 11 GET103's, the median h_{fe} dropped 20% (at 65°C) during the first few thousand hours, then remained steady at least until 28,000 hours (test still running). A 500 hour life test at 85°C showed the same distribution of h_{fe} before and after, although the actual values decreased about 10%. Most of the h_{fe} tests show an early drop--which depends on the temperature--and then a stable value. The armed services have test specifications and the results of these provide additional data--especially for severe environments. Inoperative failure rates seem to be in the order of 0.01% per 1000 hours from field and life tests. Field reports are very difficult to evaluate because of the many unknown factors.

REVIEW: Actual information of this type helps to temper the exaggerated reports of reliability sometimes seen in advertising and in casual articles. The paper is well worth the attention of those who design transistor equipment. It is to be hoped that other suppliers will also publish their reliability information on transistors.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of an experimental transistorized data handling system

AUTHORS: V. J. McMullan and P. Cox, Automatic Telephone and Electric Co., Ltd., Liverpool (England)

SOURCE: The Journal of the British Institution of Radio Engineers, vol. 22, pp. 17-29, July, 1961

PURPOSE: To discuss the reliability of an experimental transistorized data handling system.

ABSTRACT: The system is transistorized (mainly) and employs printed-card techniques; the card assemblies are stacked in units which, in turn, are stacked in cabinets. The four sections of the paper are: factors which influence the reliability of a system, a brief description of the system, the commissioning and maintenance of the equipment, and component reliability. Serviceability is defined as the fraction of time the system is usable and is the most important consideration of use. (Some general principles are given for reliable, maintainable design.)

Forced air cooling (for 300 watts of power) is used. There are sufficient test points on each unit. The number of different types of units has been kept small. A central battery is used for the power supply and allows for standby power. There are prescribed fault finding procedures; written logic directories and flow diagrams are used instead of circuit diagrams. All units can be made very accessible for repair. Since reliability is so important, failure data is carefully logged. So far, the number of failures is very small--hardly enough to analyze. Some of the failure rates (in per cent per 1000 hours) for components having seen 5500 hours of service are listed here. Complete tables are given in the text.

carbon film resistors	0.001
electrolytic capacitors	0.1
germanium point contact diodes	0.003
transistors--group A	0.022
soldered joints	0.007

Extreme care must be taken in interpreting the data for other uses; a detailed discussion is given in the paper.

REVIEW: This is an excellent paper and will be of interest to those who are responsible for the design of transistorized equipment. The authors seem to be careful about the accuracy and meaning of their remarks. It is obvious that we have a long way to go in developing more-reliable parts. Another paper is expected after more operating time is accumulated.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiation and other environmental effects on satellites

AUTHOR: R. Innes, Marconi's Research Laboratories, Great Baddow, Essex

SOURCE: The Journal of the British Institution of Radio Engineers, vol. 22, pp. 241-250, September, 1961

PURPOSE: To summarize the radiation environments of satellites and to discuss the physical mechanisms of radiation damage.

ABSTRACT: The radiation environments encountered by a satellite during various phases of its orbit are summarized. The interaction of high-energy radiation (protons, electrons, neutrons and gamma rays) with matter is described together with the attendant electrical, magnetic, chemical and structural damage to materials and equipment. An argument is presented to show that shielding against hard radiation in inefficient and uneconomical. Estimates are made of the life of a transistor--the most susceptible to damage of normal electronic components--in a satellite traversing the lower Van Allen belt. Means of protection against the erosive low energy radiation are discussed and requirements to meet launching conditions are mentioned.

REVIEW: This paper is a refreshing, penetrating, and up-to-date review of basic radiation interaction phenomena which will be of interest to physicists as well as electronic engineers. The author has done a creditable job of assessing the pertinent mechanisms of radiation damage and the likely effects on macroscopic behavior of materials. Additional information and references on space radiation and shielding are given in "Radiation Shielding for Manned Space Flight," NASA TN D-681, July, 1961, by L. E. Wallner and Harold R. Kaufman available from National Aeronautics and Space Administration, Washington, D. C. See also related Reliability Abstracts and Technical Reviews, Serial Numbers 81, 89, 107, and 108.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Preventing electronic hotspots

AUTHOR: Frank W. Wood, Jr., Advanced Design, Inc., Vienna, Virginia

SOURCE: Machine Design, vol. 33, July 6, 1961, pp. 130-133

PURPOSE: To describe component layout and assembly techniques for preventing electronic hotspots.

ABSTRACT: Many electronic failures are due to poor parts selection and poor placement. Heat dissipating tube shields can reduce the tube envelope temperatures 100 to 200°C below that for the old JAN shield. Subminiature tubes should use the special heat conducting shields. Transistors also can have special mountings for heat dissipation. High wattage resistors and other heat dissipating components should be mounted so that they can easily give their heat to the chassis or to the air. They should not be boxed in by temperature sensitive components. If stacked, the bottom ones should not be directly under the top ones. Allow for air circulation around the parts and especially around cooling fins. The parts inside of encapsulated assemblies should be able to get rid of their heat without too much temperature rise. In some cases, an external heat sink is necessary even when testing the part. Forced air flows should be given careful consideration. Air paths should be laid out to give maximum flow and minimum temperature rise for all components.

Military Design Requirements for Electronic Equipment Temperatures and Cooling. Some requirements are given, for example: locate parts properly and use the chimney effect where possible; no exposed parts should be over 60°C with 25°C ambient; the thermal design must be developed along with the electronics; parts temperature ratings should be taken very seriously, they should not be exceeded during operation. There are four factors in temperature rise: ambient temperature, average rise due to total power, local hotspots due to high dissipation components and dissipation of the actual component under consideration. When the total heat is over 5 kw or the heat exceeds 10w/ft^2 of enclosure surface, water cooling should be used.

REVIEW: This is an introductory article on the subject. It can be summarized by saying--know what the hotspot temperature of each part is under actual conditions and try to keep it as low as feasible--compared to the rating. In the military design section, one does not know whether it is just "good advice" or actual summaries or quotes from military specifications.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improving analog-circuit reliability with redundancy techniques

AUTHOR: Albert A. Sorensen, Research and Development Division, Space Technology Laboratories, Inc., Los Angeles, California

SOURCE: Electro-Technology, vol. 68, October 1961, pp. 66-75

PURPOSE: To present some of the techniques for using redundancy in analog circuits.

ABSTRACT: Redundancy is easier in digital circuits than in analog circuits because of the nature of the outputs of the two. Passive (non-switching) redundancy tends to be more difficult to apply successfully than does the active (switching) kind. Several possibilities for the latter case are: (1) output dc level detection--in an ac amplifier that is dc coupled internally the dc output level will change for many types of failures; (2) carrier detection--a high frequency standard signal is added to the normal input and the gain of the amplifier is checked by it; (3) input-output comparison--the output of an amplifier can be reduced by its normal gain and compared with the input; (4) majority comparison--three amplifiers are connected to the input and only one to the output and the outputs of all three are compared; (5) several amplifiers are used and two at a time are connected, if their outputs do not agree, two more are tried, etc.; (6) alternate comparison--two amplifiers are alternately switched between a standard signal and the circuit. Some formulas are derived using the constant failure rate assumption--both for passive and active redundancy. Many examples are worked out in detail. A reliability improvement factor (RIF) is defined and then calculated in the examples. This factor is better, the shorter the time that is considered.

REVIEW: This is a rather extensive discussion of analog redundancy, although not all of it is new in the literature. The section on formulas for passive redundancy implicitly assumes that failure rates are independent of the state of the other redundant parts and that capacitor failure rates are independent of capacitance. There is some evidence that neither of these fits the physical situation. In a circuit showing redundant relay contacts, one of the three poles can be omitted. The RIF is defined as a reliability ratio, but is used as a probability of failure ratio. (This sort of error occurs from time to time in the literature; we need an easy-to-use word for "probability of failure" that is related to reliability.) In the RIF calculations the failure rates of components and auxiliary equipment are presumed to stay the same, even though power, volume, and weight may be increased. In any case involving redundancy, the reliability of the entire system should be calculated both ways to be sure that the system as a whole has actually been improved. If read critically this paper can be of help to those interested in redundancy for analog circuits. Another technique for passive redundancy in amplifier design is shown in Abstract and Review Serial Number 59.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transformer specification for reliable electronic equipment

AUTHOR: Daniel Epstein, Chief, Engineering Components Section, Radio Receptor Company, Inc., Hicksville, New York

SOURCE: Electro-Technology, vol. 68, October, 1961, pp. 76-81

PURPOSE: To show how to specify transformers with MIL-T-27A.

ABSTRACT: The MIL-T-27A specification plus its several amendments is a satisfactory vehicle for specifying reliable transformers. Over-conservative requirements do not produce more reliable transformer performance. The paper is limited to the general class of hermetically sealed or encapsulated power transformers normally utilized in military electronic equipment, classified as Grade 1, 2, 4, 5 in MIL-T-27A. Three areas of importance in transformer design are the environment, electrical requirements and mechanical considerations. These can be broken down into categories as follows.

I. Environmental Conditions
Minimum and maximum operating and storage (ambient) temperatures, vibration, shock, bounce and drop, humidity, rain, altitude, sand and dust, corrosion and salt spray, fungus.

II. Electrical Requirements
(A) Must be specified for every transformer: input voltage, operating frequency, number of secondary voltages with rms output voltage and tolerance for each, input and output currents, working (insulating) voltages, electric breakdown tests.

(B) Specify when applicable: efficiency, corona discharge, dc resistance of winding, duty cycle, electrostatic shielding, polarities, life, current waveshapes, voltage regulation.

(C) The operating or test circuit is helpful sometimes.

III. Mechanical Considerations
Dimensions and tolerances, type of terminals, mounting studs, finish, markings. Workmanship, especially inside, is difficult to specify but is very important.

REVIEW: The article details many of the important items in specifying transformers. Those who must do this from time to time would do well to have this reference handy. Since derating or overspecifying is used with many components to obtain extra reliability, the author's caution not to do so with transformers should have been explained. Reliability is rarely mentioned explicitly but it is implied that poorly specified transformers may have poor reliability.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluation by overstress

AUTHOR: W. S. Connor, The Research Triangle Institute

SOURCE: Industrial and Engineering Chemistry, vol. 53, June, 1961, pp. 73A-74A

PURPOSE: To show the value of testing to failure as opposed to testing at a given stress level.

ABSTRACT: This paper shows by means of an example that, in reliability estimation, testing to failure gives narrower confidence intervals per unit sample size than testing at a fixed stress level. In testing at a specified stress level, one tests n items, of which an observed number, say x, pass. The point estimate of the probability of success is then x/n. The confidence interval is determined from the binomial distribution. In testing to failure one tests n items by increasing the stress on each until failure occurs, thereby obtaining n critical stress levels, $y_1, y_2, \ldots, y_n$. The critical stress level is assumed to be normally distributed, and the y_i, $i = 1, \ldots, n$ are used to estimate the mean and standard deviation. The probability of success at a given stress level is calculated from tables of the noncentral t distribution.

Testing to failure uses more information, and one would expect to get more precise results. This is borne out in the numerical example by the fact that the second procedure yields the narrower interval. However, the result is very sensitive to the assumed distribution of critical stresses, especially in the lower tail of the distribution.

REVIEW: This paper illustrates an important point in reliability testing, viz. the desirability of testing to failure. The procedures and the underlying assumptions are carefully explained, and the paper should be quite readable by those not intimately familiar with statistical theory. As the author points out, the result has been demonstrated only by example, and not by a comprehensive mathematical treatment, but the demonstration is adequate to indicate the advantage of the second procedure.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Equipment reliability at British air show

AUTHOR: (SIGNAL Staff Report)

SOURCE: SIGNAL, vol. 16, September, 1961, p. 61

PURPOSE: To report briefly on British developments of ultra-reliable equipment featured at the Farnborough Air Display and Exhibition held in London, September, 1961

ABSTRACT: Recently developed electronic devices for use in aircraft and at ground control centers are intended to increase air safety. Transistorized radar equipment which has undergone more than 10,000 hours of prototype trials and achieved 99.8 per cent reliability was exhibited by Decca Radar. The reliability figure for the equipment is made possible by a system known as "environment stabilization" in which all the components and circuits are held at a constant internal temperature, accurate to within a quarter of a degree Centigrade and at a controlled humidity. Marconi's Wireless Telegraph Company has used a method of sealing off components to increase their reliability. Whenever possible, circuit sections for radio and navigational apparatus are encapsulated in a dry, inert gas in order to protect them from damage by dust and atmospheric changes. Transistorized circuits for this series underwent 30,000 hours of testing to ensure reliability. Elliott Brothers demonstrated how a general purpose digital computer, the type 803, can be programmed to carry out a wide range of air traffic control functions. Cossar Radar and Electronics presented a display of secondary surveillance radar, a method of instantly identifying radar plots, consisting of an interrogator-transmitter on the ground which triggers off a transponder in the aircraft.

REVIEW: This is a brief report and gives no details regarding the points mentioned. The reported accomplishments in the development of reliable equipment could be of general interest to those concerned with reliability.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The evolution of a low cost, standard reliability program

AUTHOR: Edmund A. Bolton, Manager, Applications Engineering, Vitramon, Inc.

SOURCE: Military Systems Design, vol. 5, September-October, 1961, pp. 8-11

PURPOSE: To describe the reliability testing at Vitramon, Inc.

ABSTRACT: Reliable systems can be achieved by using wide tolerance circuitry, by derating of components (although this may not work for some components), and by using very reliable components. The third method takes advantage of a component manufacturer's knowledge. A "standard reliability program" was begun at Vitramon in 1958. Their High Reliability Specification S-1002 was designed to provide greater reliability than required by military specifications at a low cost. Dielectric impurities generally cause bad parameter drift whereas imperfections usually cause complete failure. After partial processing of a batch, some sample capacitors are made and tested. Impurities usually cause a high dissipation factor; mix proportion errors cause a large temperature variation in capacitance. After approval, the batch is laminated, and when the build-up is completed the capacitors are cut apart. Records are kept of all stages, and since a given lot is from one batch by one operator at one time, adequate sampling is fairly easy. After firing, a sample is given a 250-hour accelerated test. Every three weeks, samples are tested for environmental resistance and solderability. Every six weeks, 300 pairs are put on long life test and compared with the accelerated tests. Through early 1961 over 32 million unit-hours of accelerated testing have accumulated, with an average failure rate on all lots of 2.5%/1000 hours. Testing at rated conditions (about 7 million unit-hours) has produced no catastrophic failures and a 0.2%/1000 hours parametric failure rate. Close correlation between failure rate in pre-production testing and finished product testing has been observed and documented [1]. Further correlation has been provided by long term life tests on reject material. A new specification S-1002B has been prepared to meet the proposals of the Darnell report and new military specifications. A new frit with better properties at higher voltages was developed. Development of a 100-hour accelerated test is under way. These programs are rather expensive, but are very worthwhile to both producers and consumers.

REFERENCE: [1] "High reliability statistically demonstrated," presented to the IRE in March, 1959 by Barton L. Weller

REVIEW: The publication of reliability efforts and results by component manufacturers is very worthwhile. This sharing of experience is an effective way of helping the electronics industry to upgrade itself. A graph (but no substantiating data) is presented on the effects of derating. While the graph is the only design information, the article may well be of interest to design engineers.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Confidence limits for system reliability

AUTHORS: Norman R. Garner and Richard W. Vail, Jr., Aerojet-General Corporation

SOURCE: Military Systems Design, vol. 5, September-October, 1961, pp. 24-27

PURPOSE: To present a relatively simple procedure for obtaining a lower confidence limit for system reliability when information is available only on subsystems.

ABSTRACT: The Product Rule yields a single-valued estimate of system reliability, given reliability information on independent subsystems. Generally, however, reliability requirements are stated in terms of a lower confidence limit for system reliability rather than in terms of a single-valued estimate. Methods for combining subsystem reliabilities to obtain a lower confidence limit for system reliability are not well defined. This paper proposes a procedure for doing this for series systems composed of unlike subsystems, for series systems composed of like items, and for parallel systems.

Given the subsystem reliability information and assuming random mating of the subsystems the possible numbers of system failures are determined. For each sampling of complete systems a lower confidence limit on system reliability, with a specified degree of confidence, is obtained through the use of tables of confidence limits for the binomial distribution. It is proposed to compute a weighted average of the possible confidence limits as the estimate of the lower confidence limit for system reliability, using as weights the probabilities of obtaining the various possible numbers of system failures. However, exact determination of these probabilities would require that the system reliability be known. The authors propose to overcome this difficulty by computing the weights through the use of the point estimate of system reliability obtained through the Product Rule. The procedure is illustrated for a simple system composed of three independent subsystems in series, the same number of tests having been performed on each subsystem.

Adaptation of the method to series systems composed of like subsystems and extension to parallel systems are briefly discussed. It is pointed out that when unequal sample sizes are available for the subsystems, the sample size in the estimate cannot exceed the smallest sample size available, although all of the information in the samples may be used in obtaining the point estimate of system reliability.

A Monte Carlo study has been made to evaluate the proposed method. The results of this study indicate that the method is preferable to the use of the Poisson approximation to the binomial. The study also shows that the method provides better estimates of confidence limits than would be obtained from complete system testing. This result is

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expected since the method takes into account all possible sampling variation arising from random fitting of subsystems to produce a single system.

REVIEW: The authors have proposed a method of obtaining a lower confidence limit for system reliability, but they have given no mathematical justification for it. In the report of the Monte Carlo study which they present as justification, no indication of the extent of the study is given, and the statements regarding the conclusions are rather vague. The potential user should therefore be skeptical as to whether the resulting indicated degree of confidence is in fact valid. The difficulty here revolves about the question of the effect of introducing the point estimate of population reliability into the confidence limit calculations. A closely related question is, of course, the effect of the sample size on which the point estimate is based. Unfortunately the authors have made no attempt in their paper to deal with these questions, thus leaving the validity of their method unjustified.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Workmanship vibration

AUTHOR: Art Shafran, Project Engineer, Philco Corporation

SOURCE: Environmental Quarterly, vol. 7, January, 1961, pp. 32-34

PURPOSE: To discuss a method for inducing workmanship vibration in equipments weighing 300 to 1,000 pounds, together with a way of determing criteria adequate for an effective test.

ABSTRACT: To guard against faulty assembly of its TV sets, Philco subjects them to vibration tests on the production line and turns them on for a quick check of reliability by observing the screen. This relatively inexpensive means of testing, known as workmanship vibration, has been adopted for the company's military electronic equipment, too, with excellent results. Operating the equipment during vibration is more important to uncovering possible intermittent trouble than before- and after-vibration operation. (Author)

For this purpose the use of normal vibration equipment was found to be impractical, because of the need to carry out the tests on the racks of chassis in their assembled positions, and with the sets operating during vibration. Factors affecting the choice of a vibration source are (1) the desired vibration level, (2) where to monitor the vibration, and (3) duration of the vibration. The paper describes the solution found for the problem.

Experience in setting up this test has led to the following recommended approach when attempting workmanship vibration for military electronic or similar equipment:

1. Determine vibration level based on pretesting representative equipment. Several levels may be required for a wide range of component types appearing in the chassis.
2. Determine number of equipments to be tested together. This can be called the workmanship vibration module.
3. Determine where vibration monitoring will best represent circuitry vibration.
4. Determine energy required to vibrate the largest and the smallest module.
5. Determine vibrator, fixtures and holding method for test.

REVIEW: This paper is a fairly detailed account of the solution found by one company to a vibration-testing problem. As such it will be of interest to those faced with similar problems in the testing of electronic equipment.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Minimization of test programs by proper classification of environmental factors

AUTHORS: Norman R. Garner, D. E. Hartvigsen, and S. Roy Wood, Aerojet-General Corporation

SOURCE: Environmental Quarterly, vol. 7, April, 1961, pp. 14-19

PURPOSE: To discuss the value of proper classification of environmental factors in reliability testing.

ABSTRACT: With ever deeper space probes, more reliable components are needed for the vehicle to survive in attendant new sets of severe, complex environmental conditions. As the range of environmental conditions is extended, so developmental costs increase in the search for more reliable systems. Proper classification of environmental factors and use of statistical methods can effect large economic savings in test programs, provide assurance of maximum information from test results and allow efficient estimation of "operational reliability." (Authors)

The concept of an environmental parametric space is described and illustrated. As a result of the dynamic nature of this parametric space, a component is subjected to a stress spectrum that is unique for that component. The number of combinations of environmental conditions for the system is therefore infinite. It is necessary to condense this number to something manageable in designing an optimum test program. An important method of doing this is the preparation of a list of mutually exclusive sets of environmental factors. A suitable list, involving ten categories, for the testing of most rocket-powered space vehicles is cited. Another approach is the determination of the environmental periphery, or a delineation of the extremes of the conditions to be encountered. An example is given of a test program established in this way, taking the form of a 2^6 factorial experiment. The possibility of further reducing the size of a test program through the use of fractionally-replicated factorial designs is mentioned. Further considerations include the classification of environmental factors according to the effects of failure of the system on the direction of the development program and on operational performance, and the scheduling of tests according to the method of detecting an environmental effect. An example is given, related to the component proof-testing program of a plastic-cased high-altitude igniter.

REVIEW: The points discussed in this paper will be of interest to those concerned with the environmental testing of complex electronic systems. The potential user of the ideas will of course have to adapt them to the conditions of his own situation.

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It would have been desirable for the authors to have given a more detailed explanation on certain points. For example it is not very clear from the paper just what the term "mutually exclusive" means as applied to sets of environmental factors. No justification is given for the choice of the particular design used in the example. It would appear that the analysis could yield only the main effects and the interaction between the "fire" and "soak" effects. Presumably the other interactions are assumed to be neglible, but no statement is made regarding this. It is not possible to tell from the information given just what effects are confounded in the design.

There seems to be a difficulty regarding the footnotes on the tables in the paper. The numbers in the cells in Tables I and II are apparently identification numbers for the treatment combinations, whereas those in Table III are numbers of replications. The footnotes in all three cases identify these as "the environmental factors to be tested."

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Ultra-reliability

AUTHOR: William Belt, Associate Editor

SOURCE: Electronic/Electromechanical Production, First Issue, pp. 22-23

PURPOSE: To describe the experience of a potentiometer manufacturer in achieving the production of an ultra-reliable product.

ABSTRACT: After several years of thought, trial and experimentation, Bourns, Inc., Riverside, California, in late 1959 standardized a program to achieve the highest possible reliability in a Trimpot lead screw actuated potentiometer. The first step in developing the program was the selection of the model currently in production having the maximum inherent design reliability. This resulted in a saving of lead time, and took advantage of the availability of two years of test data.

Special production controls were set up for the ultra-reliable line, and the operation was kept isolated from that of standard production lines. Production quantities were limited to small, easily workable lots, and lot control was so set up as to enable the tracing of all individual parts which went into a finished unit. The sampling inspection and record-keeping procedures are described.

An extensive test program has been set up to check on the achieved reliability. Nine hundred units have been started on a 10,000-hour load life test. Final acceptance testing includes vibration, humidity, and rotation cycling tests. Wear-out curves have been established for such environments as various power levels, high temperature exposure, temperature cycling and humidity. An initial failure rate goal of 0.01% per thousand hours was set, but a program is under way to improve this goal to 0.001% per thousand hours.

REVIEW: This paper describes the production control and quality control steps taken by one company in the manufacture of a high-reliability component. The description may well be of interest to those concerned with setting up similar programs.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluating diode reliability

AUTHOR: EDN Special Report based on an interview with Dr. D. M. Van Winkle, Vice President Technical Director, Continental Device Corporation, Hawthorne, California

SOURCE: Electrical Design News, vol. 6, December, 1961, pp. 76-80

PURPOSE: To discuss the factors involved in the evaluation of diode reliability.

ABSTRACT: Diode failures may be divided into two broad categories: mechanical failures which result in various open and short circuit conditions, and changes in the reverse leakage path which cause degradation of the reverse characteristics. Evaluation of the reasons for these failures can lead to a higher degree of reliability.

The mechanism of reverse leakage is explained. The variability of this characteristic with age, temperature, voltage, and electrical use is reflected directly in the diode reverse properties. Soft knees in the junction characteristic at the initiation of reverse conduction are caused by excessive contamination at the junction, or by leakage paths which shunt the junction. If the contaminants or insulating materials break down or change with use, age, or temperature, reliability cannot be assured. Observation of the forward properties of a diode cannot reveal intrinsic parameter drift problems. In all cases, noticeable changes in forward properties result from mechanical discontinuities or short circuits.

Shock and vibration tests are used in the evaluation of mechanical integrity. Life tests are usually conducted with significant power being generated only during periods of forward conduction. Thus knowledge of the reverse breakdown characteristic is not obtained. The repeated cycling of a junction in the reverse direction and observing any possible change in the sharpness of the onset of avalanche conduction is recommended as an excellent way of evaluating the reliability to be expected from the device. A pulse test circuit which will apply this repeated cycle is given. The principal points made in the paper are conveniently summarized at the end.

REVIEW: The facts and advice given in this paper should prove useful to those concerned with selecting diodes to obtain maximum reliability, or with the evaluation of manufacturers' specifications on these devices.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Gamma distribution in acceptance sampling based on life tests

AUTHORS: Shanti S. Gupta and Phyllis A. Groll, Bell Telephone Laboratories, Inc.

SOURCE: Journal of the American Statistical Association, vol. 56, pp. 942-970, December, 1961

PURPOSE: Under the assumption of a gamma distribution of lifetime, to find the minimum sample size necessary to assure a certain mean life when the life test is truncated at a preassigned time and when the observed number of failures does not exceed a given acceptance number.

ABSTRACT: The gamma distribution is assumed as a model for lifetime. The problem of acceptance sampling when the life test is truncated at a preassigned time is discussed. For various acceptance numbers, various confidence levels, and various values of the ratio of the fixed experiment time to the specified mean life, the tables of this paper give the minimum sample sizes necessary to assure the specified mean life. The operating characteristic functions of the sampling plans are obtained and these are graphed for a few selected cases. Producer's risk is discussed and a small table is given for the ratio of true mean life to a specified mean life which insures acceptance with a probability of $P^* = .95$. An approximation is given for the minimum sample size problem. Failure rates for the gamma distribution are tabulated. The use of the tables is illustrated by examples in most cases. (Authors)

REVIEW: This paper is a valuable contribution to the methodology related to the design or evaluation of acceptance sampling plans for life testing. Approximately half of the length of the paper is devoted to the tables; the examples should prove very useful in illustrating their use.

It should be noted particularly that the procedures described are based on the gamma distribution, and that the shape parameter must be known. References are cited to related work by other authors based on the exponential distribution and on the Weibull distribution (see, for example, Abstract and Review Serial Number 46). The literature review given in the paper adequately conveys the orientation of the present work with respect to other relevant publications.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A bivariate extension of the exponential distribution

AUTHOR: John E. Freund, Arizona State University

SOURCE: Journal of the American Statistical Association, vol. 56, pp. 971-977, December, 1961

PURPOSE: To present a bivariate extension of the exponential distribution designed for the life testing of two-component systems, which can function even after one of the components has failed.

ABSTRACT: A bivariate extension of the exponential distribution is proposed as a model for the life testing of two-component systems, which can function even after one of the components has failed. Examples of situations in which the model might apply are the study of engine failures in two-engine planes, the wear of two pens on an executive's desk, or the performance of a person's eyes, ears, kidneys, or other paired organs.

The joint density is derived for the two random variables X and Y representing the lifetimes of two components A and B in a two-component system. The basic assumptions are that X* and Y* are independent random variables having exponential distributions, where X* represents the lifetime of component A if component B is replaced with a component of the same kind each time it fails, and Y* is similarly defined for component B. In the joint density there is a dependence between X and Y resulting from the fact that the failure of the B component changes the parameter of the exponential life distribution of the A component, while the failure of the A component changes the parameter of the exponential life distribution of the B component. Various statistical properties of the model are investigated, including maximum likelihood estimates of the parameters and their distributions.

REVIEW: This is a mathematical paper which will be of more interest to the theorist than to the design engineer. However, the author does specify quite clearly the type of situation to which the proposed model is applicable.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Long life attainment with subminiature tubes

AUTHOR: P. J. Erdle, Field Engineer, Sylvania Electric Products, Inc., Emporium, Pennsylvania

SOURCE: Sylvania engineering information service, vol. 8, October, 1961, 11 pp.

PURPOSE: To present life data on popular subminiature tubes.

ABSTRACT: Life tests were run on two plug-in units used on a naval shipboard equipment: a Video Amplifier and a Trigger Generator. Bulbs are cooled so that their temperatures do not rise more than 25°C above ambient; shock and vibration are not important. The table below shows some of the results.

tube type	ambient temperature	life expectancy (hr.) minimum	life expectancy (hr.) maximum
5639	30°C	27,000	(1)
5639	80°C	4,000	15,000
6021	30°C	25,400	(1)
6021	80°C	(2)	(2)

(1) in excess of test: 31,700 hr. (2) in excess of test: 20,100 hr.

Static cycled life tests have been run on the 5639, 6021, 5840 and 6111 tubes under a variety of stress conditions. The results for these are shown as sets of distribution curves. Improvements have been made in these tubes since the tests were run; thus these results should be used only as benchmarks until the newer data are available.

REVIEW: The results are presented in terms of distributions in the case of static cycled life tests and, as such, could be quite helpful. The term life expectancy is used in describing the equipment life tests and its meaning is not quite clear since the numbers seem to be maximum and minimum sample lives.

The publication of these results is most worthwhile in that it presents concrete facts as a basis for design. It is to be hoped that Sylvania will publish more of these data and that other companies will do the same.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLES: Electron tube reliability prediction
Radiation--an emerging electronics environment (two papers)

AUTHOR: A. J. Heitner

SOURCE: Sylvania engineering information service, vol. 8, November 6, 1961, 6 pp.

PURPOSES: To present life data and derating factors for subminiature tube types; to give some idea of the resistance of tubes to nuclear radiation.

ABSTRACT: Very few reliability numbers on specific tubes are now available. The "Darnell report" points out the need for this sort of data. A program has been instituted (Sylvania) to incorporate reliability data on technical data sheets. The base failure rate is given and correction factors are used for heater voltage, total power dissipation in the envelope, and bulb temperature. Tables and curves for this purpose are included.

Nuclear radiation is becoming part of the environment for some electronic tubes. The data here are for steady state neutron exposure (not pulses) at a rate of 10^{12} neutrons $cm^{-2}sec^{-1}$ and a total exposure of 10^{16} neutrons cm^{-2}. There were no bad effects either electrical or mechanical after exposure although the glass envelope did discolor to some extent. Determination of possible effects on an operating tube during exposure is quite difficult but there seems to be no effect from an exposure similar to that above. Pulsed radiation is usually accompanied by stray electric fields which make measurements during operation very difficult. Again--there seems to be no effect in some preliminary tests (4 μsec pulse at 10^6 R/sec).

REVIEW: The publication of increasing amounts of data on reliability is very worthwhile and is to be encouraged. The nuclear data are of narrower interest, but are nevertheless important. Some details, such as particle energy, are not given.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Vibration testing and the perpetuation of mystery

AUTHOR: Jack Fromkin, Rototest Laboratories

SOURCE: The Journal of Environmental Sciences, vol. 4, October, 1961, pp. 14-15, 18

PURPOSE: To point out the inadequacies in the present state of vibration testing and to discuss the lack of progress in the area of anti-vibration design.

ABSTRACT: Vibration is only one of many existing environmental stresses, but it accounts for a disproportionate share of the malfunctions and failures observed. While good progress has been made in design to combat the effects of other environments, little has been accomplished in the area of anti-vibration design. Failure rates under initial vibration testing are very high, and present methods of vibration testing do not provide the knowledge needed for redesign. It is mandatory that existing test methods be examined and modified.

The prediction of vibration response for a typical package by analytical means is exceedingly difficult; hence knowledge of the response must come from the testing process. In typical vibration testing procedures no attempt is made to observe the internal dynamics of the package, although output information is taken from the case. The difficulties with this monitoring process are discussed.

No amount of control imposed on the input will compensate for failure to properly investigate the output. The most promising method of "reading the output" (observing the internal dynamics of encased components) seems to be X-ray. However, the limitation in the application of X-ray techniques is the state of the X-ray art. There is an urgent need for further investigation into any technique which will gather the information required to make a truly useful tool of vibration testing.

REVIEW: This paper emphasizes the shortcomings and difficulties in the present state of vibration testing, in an effort to encourage further work in this area. It may be, however, that more emphasis than necessary is placed on the negative aspects of the situation. The reader interested in this topic should refer also to two letters to the editor appearing in the December, 1961 issue of The Journal of Environmental Sciences, p. 18. One of these letters discusses the results of a development program carried out by Zenith Radio Research Corporation which has accomplished a considerable improvement in the state of the X-ray art, making it possible to X-ray monitor specimens continuously during vibration testing.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improving electronic reliability

AUTHOR: Morris Halio, Plans and Programs Office, Headquarters, U. S. Army Transportation Materiel Command, St. Louis, Missouri

SOURCE: IRE Transactions on Military Electronics, vol. MIL-5, pp. 11-18, January, 1961

This paper is virtually the same as the one covered in Abstract and Review Serial Number 141, although neither paper cites the other.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability screening of electronic component parts

AUTHOR: Ralph E. Thomas, Battelle Memorial Institute, Columbus, Ohio

SOURCE: Nondestructive Testing, vol. 19, pp. 410-415, November-December, 1961

PURPOSE: To illustrate the application of linear discriminant analysis to a quality inspection example.

ABSTRACT: The use of a linear discriminant function as a performance prediction criterion in a 100 percent inspection program is illustrated by an example in this article. One hundred and twenty PNP small-signal transistors were operated in 100°C temperature at full power dissipation for 1000 hours. At the onset of the test, nine variable characteristics of each transistor were measured and recorded. At the conclusion of the test, the performance characteristic, measured in terms of one of the nine parameters, of each transistor was recorded, and the transistors were ranked from high to low according to these values. The sixty highest ranked transistors were designated as a superior performance group; the sixty lowest transistors were designated as an inferior performance group. A linear predictive function in the onset variables was constructed by the discriminant analysis technique. The accuracy of prediction of the performance of the 120 test transistors is presented as a partial verification of the application of discriminant analysis to screening problems.

REVIEW: The choice of a linear discriminant function as a multivariate-summary criterion to be used in inspection screening has received considerable support in some recently printed papers. The important contribution made by these papers is the stimulation of interest among industrially oriented readers in the statistical procedures which have been developed for summarizing and weighting the individual characteristics of a many-character random observation. A brief, clear exposition of the methodology of the discriminant screening technique has been given to us here by Mr. Thomas.

Unfortunately, the pitfalls one can encounter in an improper application of the analysis have not been emphasized sufficiently. By trying to present a good case for this screening technique, the author of this paper has obscured rather than clarified these dangers. Let us examine individually the theoretical basis of a discriminant analysis and the reported results which should be questioned closely before one can decide whether or not the reliability screening procedure is applicable to his own inspection problems.

Given two, k-variate, normal populations $N[\mu_1, \Sigma]$ and $N[\mu_2, \Sigma]$, which have a common set of variances and covariances, Σ, but differing sets of means, μ_1 and μ_2, the object of a discriminant analysis is

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to distinguish first if $\underline{\mu}_1 \neq \underline{\mu}_2$ and then, if this is indicated to be true, to designate a set of coefficients, $\underline{\lambda}$, such that the linear function

$$z = \underline{\lambda}'\underline{x} = \lambda_1 x_1 + \ldots + \lambda_k x_k$$

in k observational variates indicates most accurately to which population subsequent multivariate observations $(x_1, x_2, \ldots, x_k)$ belong. The appropriate statistic for deciding on the basis of a discriminant function whether or not two populations differ is the F test given by $(\bar{z}_1 - \bar{z}_2)^2/s_z^2$ where the $\bar{z}_i$ are random sample mean values from the two discriminant function populations and s_z^2 is the pooled estimate of error variance. The statistical power of the F test is a monotonically increasing function of

$$(\mu_{z_1} - \mu_{z_2})^2/\sigma_z^2 = \underline{\lambda}'(\underline{\mu}_1 - \underline{\mu}_2)(\underline{\mu}_1 - \underline{\mu}_2)'\underline{\lambda}/\underline{\lambda}'\Sigma\underline{\lambda}.$$

Hence, choosing $\underline{\lambda}$ to maximize this ratio, one obtains

$$\underline{\lambda}' = (\underline{\mu}_1 - \underline{\mu}_2)'\Sigma^{-1}$$

which is estimated by

$$\hat{\underline{\lambda}} = (\bar{\underline{x}}_1 - \bar{\underline{x}}_2)'S^{-1},$$

the discriminant weights given in the paper under review.

According to the author, the transistor data have been transformed to approximate closely the normality assumption. However, from the severely censored data presented to the reader (only 4 of 60 observations in each quality group are given), it appears that the variances of the variates in the superior group are as much as ten times as great as those in the inferior group. Thus, there is little evidence to support the assumption that the quality populations, even if they are normal, have a common variance-covariance set. (This applies also to the sample of discriminant values where one calculates variance estimates and finds $s_{z_1}^2 \doteq 10 s_{z_2}^2$.)

If the violation of basic assumptions is minor, the question of the appropriate sample size for estimating the discriminant function weights is not. Recent theoretical work on special types of discriminant functions has indicated that the estimation of discriminant coefficients is done very inefficiently. Even in this example with a large number of degrees of freedom for the variance-covariance estimates, S, it appears that the coefficients of variation of the estimated weights must exceed 0.13.

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The variability features of the estimated coefficients do not stand out in the partial verification of the reliability screening method presented in the paper because the weights were obtained from large samples and because the verification has been done incorrectly on the same sample from which the discriminant estimates were obtained. The excellent results of the verification are influenced by the fact that the interval between the two sample quality groups is large relative to the range of the inferior group and the fact that the estimated weights were obtained by maximizing the F statistic for this particular sample. A more valid verification would be obtained by summarizing the prediction results from applications of these estimated weights to subsequent random samples of transistors. These summaries then should be compared to summaries of such simple techniques as prediction based on the early life measurement of the desired performance criterion for an evaluation of the practical worth of the reliability screening procedure.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Long-term transistor reliability

AUTHOR: Erwin A. Herr, Semiconductor Products Department, General Electric Company, Syracuse, New York

SOURCE: Electronic Equipment Engineering, vol. 9, October, 1961, pp. 61-64

PURPOSE: To present some long term effects which have been observed in germanium transistors operated under various life test conditions for periods up to 40,000 hours.

ABSTRACT: Data are presented on groups of pnp germanium alloy junction transistors tested for periods up to 40K hours under several operating-life and shelf-storage conditions. One group consisted of 15 non-gettered type 2N43 transistors operated at 150 mw dissipation at room temperature. These units were operated for 40,560 hours. The results showed a gradual increase in I_{CBO} and a decrease in h_{fe} with time. The second group consisted of 1150 type 2N525 transistors, similar to the 2N43 except that this unit has a getter, which were tested for 1000 hours under the conditions of shelf storage at 25°C, oven storage at 100°C and 135°C and 200 mw cycled life. The oven storage test at 135°C produced the highest stress level for h_{FE}. Approximately 50 units in each test condition were tested for 10K hours under the conditions of 85°C and 115°C oven storage and 200 mw operating and cycled life. The results at the end of this time showed that the failure rate for the 115°C oven storage was about twice that for the 85°C oven storage group. A type 2N396 transistor was used in the third group of tests. A 150 mw cycled life test was applied to 100 units and another 50 units were subjected to an oven storage test at 100°C--both sets of units were tested for a total of 10K hours. Results showed that the 100°C storage was the more severe test condition. An additional 50 units each were subjected to a 200 mw cycled life test and a 200 mw accelerated life test. The accelerated test consisted of a 4 minutes 10 seconds power-on period and a 50 second power-off period for each cycle, whereas the cycled life test consisted of a 50 minute power-on period and a 10 minute off period. The results showed that the accelerated life test produced the highest rate of degradation failure. The degradation or catastrophic failures were determined by limits placed on the h_{FE} or I_{CBO} parameters, as measured at room temperature.

REVIEW: The material presented is very interesting and represents a considerable amount of data. The data on the 2N525 and 2N43 transistors should be of considerable use in comparing similar units with and without getters. In a private communication the author has pointed out that only two parameters, h_{FE} and I_{CBO}, were reported on during this series of tests because they have been found to be the most sensitive for indicating the reliability of the devices reported.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: High stress aging to failure of semiconductor devices

AUTHOR: G. A. Dodson and B. T. Howard, Bell Telephone Laboratories, Incorporated, Murray Hill, New Jersey

SOURCE: Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 262-272, January, 1961

PURPOSE: To present a new approach to the problem of reliability testing which will give definitive answers about the life expectancy of a device in a relatively short time.

ABSTRACT: Accelerated testing of new devices is becoming increasingly important in order to keep pace with system development programs. Such accelerated tests complement actual field use and simulated life testing and provide information pertinent to the degradation region (Region III) of the generalized failure rate pattern curve.

In the experimental design the technique is to age the devices by fixing time and varying stress until failure occurs. The stress level is increased successively in pre-selected steps. If these stress steps are not sufficiently large to permit the previous effect of stress to be neglected, then a correction factor must be applied.

To perform this technique of accelerated aging, a relatively short time and small number of devices is required. It is particularly useful in a comparative evaluation of new devices, new processing, or day to day production.

Experimental results are given for the 2N559 which is a pnp diffused-base germanium mesa transistor intended for low power (150 mw) high speed switching.

From the experiment the authors draw the conclusion that the demonstration of the normal distribution of failure in reciprocal temperature (absolute) and the log-normal distribution of failures in time along with the constant variance for these distributions are in keeping with some physical model for device degradation.

REVIEW: This very well written paper should be of considerable interest to any engineer or statistician who is concerned with the reliability of components and the techniques used to determine this reliability.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The space environment and its effects on materials and component parts

AUTHORS: S. N. Lehr and V. J. Tronolone, Space Technology Laboratories, Los Angeles, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-10, August, 1961, pp. 24-37 (presented at the Joint Reliability Seminar, Los Angeles Section, IRE, under the sponsorship of the PGRQC, PGCP, and PGED, Los Angeles, California, December 5, 1960)

PURPOSE: To summarize the available knowledge about particles and conditions in space and how they affect materials and components.

ABSTRACT: Information has been gathered on what materials can be used successfully and how these materials react in various space environments. The information has been compiled from a literature survey and from experience and is presented as an aid in the design and fabrication of electronic equipment for space vehicles. Much of the information on which data are presented is not available in the usual engineering handbooks.

In addition to the factors presented in this paper, other items must be considered, such as the exact nature of the missile of a space vehicle, the type of orbit, the length of time the vehicle is expected to function, the reliability objective, and similar goals. Regardless of the mission, certain general effects of the space environment present problems which must be met in the design itself. It is with these general effects that this paper is concerned. Topics included are as follows.

THE SPACE ENVIRONMENT

1. High vacuum
2. Magnetic fields
3. Gravitational fields
4. Micrometeorites
5. Cosmic rays
6. Electromagnetic radiation
    (a) Ultraviolet rays
    (b) X-rays
    (c) Gamma rays
7. Neutrons
8. Charged electron and proton particles

EFFECTS OF THE SPACE ENVIRONMENT ON MATERIALS AND COMPONENT PARTS

Effects other than radiation
    Temperature effects and control
    High vacuum effects

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R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

Plastics
Metals
Micrometeorite effects
Other environmental factors

Effects of radiation environment in space
Background and definitions
Penetration of radiation in material
Radiation damage mechanisms
Effects on metals
Effects on inorganic materials
Effects on organic materials
Effects on electronic parts

REVIEW: This will be a very useful summary and introduction to the subject for those who are doing design work and for those whose interest is general. There are 56 references for those who wish to pursue the subject further. Since this is a field in which papers are widely scattered, such summaries as this serve a very useful purpose. It would be very helpful if it could be kept up-to-date from time to time and if the delay before publishing could be reduced.

Additional information and references on space radiation and shielding are given in "Radiation Shielding for Manned Space Flight," NASA TN D-681, July, 1961, by L. E. Wallner and Harold R. Kaufman available from the National Aeronautics and Space Administration, Washington, D. C. See also related Reliability Abstracts and Technical Reviews, Serial Numbers 81, 89, 107, 108, and 145.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Small subcontractors in reliability programs

AUTHOR: Donald C. Berman, Fairchild Astrionics Division, Fairchild Engine and Airplane Corporation, Wyandanch, L. I., New York

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-10, August, 1961, pp. 38-41 (presented at the third meeting of the Long Island Reliability Forum, Huntington, L. I., New York., September 20, 1960)

PURPOSE: To show how small contractors who do not have adequate reliability programs can be used to serve a large contractor.

ABSTRACT: Today's military systems contracts invariably have numerical and organizational reliability requirements. With systems of any size, it is advantageous for the prime contractor to subcontract out many equipments and units. Small firms often provide superior specialized technical competence, more favorable prices, faster delivery, and a more conscientious effort; however, the small firm's lack of continuing and repetitive contractual requirements for reliability usually results in organizational weakness in this area. These firms are unable to support the cost of permanent reliability, standards, and quality control functions of the type required by these contracts.

A standard comprehensive quality or reliability survey would eliminate these organizations from competition, and a superficial survey leading to their acceptance would result in the acquisition of an ineffective subcontractor. As a substitute, a specially designed analytical survey is performed which investigates the quality, reliability, standards, and design functions of the prospective subcontractor, and indicates not only the deficiencies, but also the remedial action required.

If, on the basis of price, delivery and technical competence, a firm in this category is awarded a subcontract, procedures are instituted which invariably result in a reliability achievement at least equal to that of some large organizations which, at times, have inflexible and incompatible procedures. This paper describes, in brief, the survey techniques and the remedial procedures instituted. (Author)

One of the major points is that the subcontractor is treated as a part of the main firm insofar as reliability is concerned. The subcontractor can have statistical work, design reviews, failure analyses, and preferred parts lists from the main firm. Assistance is many times given before it is requested rather than after something has been rejected.

REVIEW: This approach differs from some others that have been published. Those in small firms who are responsible for design will be interested in this paper.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The economics and reliability of multifunction devices

AUTHOR: J. A. Davies and C. D. McCool, Receiving Tube Department, General Electric Company, Owensboro, Kentucky

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-10, August, 1961, pp. 42-52 (presented at the Fall Radio Meeting, IRE and Electronic Industries Association, Syracuse, New York, November 2, 1960)

PURPOSE: To show that multifunction tubes can be more reliable and cheaper than single-function tubes.

ABSTRACT: The "Compactron" carries the multifunction concept a step further along than the 6T8,6BW8, etc. Two or three of them could replace the five or six conventional tubes, respectively, in a home radio. The Compactron has a 12 pin bottom-exhausted envelope. The 12 pin circle, with heater pins at one and 12, provides easier and better mechanical support for the electrodes. Better voltage isolation is obtained and glass electrolysis is reduced. The T-9 (1 1/8 inch diameter) bulb allows plenty of room for the elements and will even allow some elements to be horizontal. High power tubes will use a T-12 bulb and be single-function. A single heater element may supply heat to as many as three cathodes and thus many welds are eliminated. The larger bulb reduces envelope temperature. Examples are given of Compactron bulb temperatures and those of tubes they replace.

Failure estimates are obtained from the combined failure rates of the prototypes times a structure and a temperature factor; the product of the two factors is to be less than one. Life tests of tubes showed two things: (1) both drift and catastrophic failure rates on tube life tests are two to three times as high as those on set life tests and (2) drift failure rates are low on both tests so that only catastrophic failures are considered here. The structure factor contains subfactors, such as H-K failures and element shorts, which are the same in both types of devices, and subfactors, such as open heaters and open welds, which are variable due to their relative number. In one example, the structure factor is 0.72. A rather extensive analysis of bulb size and power dissipation effects on temperature was made. The several curves all had indexes of correlation over 0.90 which is considered rather good. One example showed the temperature factor to be 0.45. Tables are given for seven Compactrons and their prototypes which show bulb temperature, power dissipation, temperature and structure factors and finally, the estimated ratio of Compactron failure rate to prototypes failure rate. These factors range from 22% to 55%. Examples are given of failure rates of current multifunction tubes vs. their prototypes, e.g., 6BW8 vs. 6CB6 and 6AL5. These ratios vary from 29% to 67%

and are tangible evidence that multifunction tubes can be more reliable than several single-function tubes.

Even though envelope costs are higher than for the combined prototypes, both initial and replacement costs are estimated to be appreciably smaller for Compactrons.

REVIEW: No actual failure rates of Compactrons are given, nor is any mention made of the actual market appearance of these tubes. Anyone adding to the already tremendous proliferation of tube types should have very good reasons, other than sales gimmicks, for doing so. A problem with the multifunction tubes may be that the number of combinations of prototypes will be extremely large. This could keep the costs up and make stocking of replacements rather difficult. If restraint is exercised in their proliferation and if they do, indeed, turn out to be more reliable and less expensive, the Compactrons may be a boon to electronics.

In the analysis of variance, the mathematical model for bulb-temperature vs. bulb-size and total dissipation is not given, nor are the assumptions stated upon which the analysis is based. The importance of doing this is emphasized by the more-than-occasional occurrence in the literature of serious errors resulting from misapplications of mathematical techniques.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some aspects of satellite and space probe reliability

AUTHORS: T. W. Gross and H. C. Werner, Missiles and Space Division, Lockheed Aircraft Corporation, Sunnyvale, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-10, November, 1961, pp. 7-14

PURPOSE: To discuss some of the components problems in long-lived space vehicles.

ABSTRACT: Components with "super" characteristics are needed for these programs. To get them, a four point program was established: (1) Establish an active center for the collection and utilization of existing data. (2) Conduct evaluation and development programs to complement existing data and fulfill additional requirements to derive an acceptable class of parts. (3) Prepare high reliability procurement specifications based on data listed above to ensure that adequate parts can be repetitively purchased. (4) Prepare application criteria for use by design engineers. In 1959 a subcontractor data exchange program was organized. The Polaris, NOL Corona, Battelle ECRC, and IDEP programs of data utilization, as well as some informal programs, are used. These are summarized on a master chart. While unnecessary duplication of tests should be avoided, the satellite program has different requirements for some components than do other programs.

Tantalum capacitors are ideal from a size and weight standpoint, but many of them cannot stand the necessary stresses--especially the non-hermetically sealed types. Trimming pots, which must be stable once sent aloft are also a problem. Their elimination is not yet feasible. The present main deficiency seems to be a short life due to leakage at the shaft and consequent moisture attack. Magnetic latch relays are useful because of the zero standby power. A comparison test of these units is out for bids now. The relays will be subjected to increasing stresses to reveal failure modes. Long-life thermostats accurate to 1°F are hard to find. One vendor's test unit shattered when shipped by commercial aircraft (a very cheap environmental test indeed). Procurement specifications are also in need of study. Some new features are reliability requirements at the 90% confidence level for failure rates of 1.0%, ..., 0.001% per 1000 hours and life tests extended to 2000 hours with some out to 10,000 hours. After the part has been accepted, it must be intelligently applied. The drift of the parts due to various space environments must be known.

REVIEW: While the paper does not contain design information per se, the progress being made in component knowledge is of interest. An interesting sidelight is the performance evaluation revealed here vs. that stated or inferred in the advertising literature. One disadvantage of these testing programs for many commercial people is the restricted dissemination of the results. Perhaps some way can be found to overcome this.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design by worst-case analysis: A systematic method to approach specified reliability requirements

AUTHORS: W. D. Ashcraft and W. Hochwald, Electromechanical Systems Department, Inertial Navigation Division, Autonetics, Downey, California

SOURCE: IRE Transaction on Reliability and Quality Control, vol. RQC-10, November, 1961, pp. 15-21

PURPOSE: To show why worst-case design is good for high reliability.

ABSTRACT: The two worst-case criteria are: (1) a component (defined as an assembly of parts) must have all performance parameters within tolerance when all of its part parameters are at their worst-case values (defined as those values, not mutually exclusive, which lie within the tolerance limits, but affect the performance parameter in the worst possible way); and (2) no part shall be stressed over its specifications regardless of the conditions of component operation. These criteria: (1) enable rapid evaluation of performance quality of a circuit, (2) are rarely too severe, (3) do not result in overly-complex devices, (4) are necessary and sufficient to predict minimum component reliability when valid parts reliability data are available. There are additional benefits to the whole organization from using this method. (Various justifications and explanations are given in the paper.) In order to carry out this analysis, there must be a complete determination of circuit performance and allowable tolerances and of all damaging stresses. A circuit may have many states and it should be analyzed for each one. Where worst-case design is too disadvantageous, a method is given for a narrowing of the values. A complex circuit, such as a radio receiver, can be broken up into subcomponents, each of which is considered separately. (A section of the paper discusses the relation of worst-case criteria to statistical theory.) Reliability prediction in a balanced worst-case design is easy because the failure rates of parts can be added to give the component failure rate. (If a part failure does not actually cause component failure, the answer will be too high.) Appendix A is a derivation of the method for worst-case tolerance narrowing and Appendix B is an example of a circuit designed to meet worst-case criteria.

REVIEW: This paper is an ardent argument for the use of worst-case design. Although it is stated that the subject is not new, no specific references are given, nor are the variations on absolute worst-case design mentioned. Some of the points which are stated as fact are argued from time to time in the literature, e.g., that worst-case design is not too severe and that it does not result in overly complicated devices. Some of the advantages claimed for the design are also true for any acceptable design method, e.g., it allows for correlation effects due to common stresses, and the use of poorly analyzed or inadequately understood

designs is eliminated. The blanket statement that "... end-point calculations do not involve statistical or nonlinear theory" probably has exceptions. The use of the comparative degree (more, better), without specific references to the other thing being compared, is inappropriate in a technical article. The purpose of the section on "Relation of worst-case criteria to statistical theory" is not clear. Some phrases in it are also not clear, e.g., "The worst-case criterion must be met; if it is not...". It is forced to be met, yet we consider what happens when it is not. The discussion on parts failure rate vs. component failure rate fails to mention explicitly the safety factor argument given earlier. The derivation of the variance (in Appendix A) is not the conventional one and if it is actually different, it should be justified. If, however, it is supposed to be conventional, it is quite wrong. In the Taylor's series expansion, the function and its derivatives are evaluated at the point of expansion (in this case, the point is the true mean). In addition the expansion is exact only for a linear function; otherwise, the assumption is made that higher order terms are negligible.

Worst-case design does have many merits and, if this paper is read critically, it can contribute further understanding.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Built-in reliability

AUTHOR: E. P. Laffie, CBS Electronics, Division of Columbia Broadcasting System, Incorporated, Danvers, Massachusetts

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-10, November, 1961, pp. 28-35

PURPOSE: To show how changes in production methods can improve product reliability.

ABSTRACT: One of the basic concepts for achievement of true reliability is to build the product right in the first place. Two approaches to this are (1) coordination of production, engineering, and quality control groups and (2) continuous analysis and evaluation of rejects. The four reject sources are from the inspection department, from life tests, from customer life tests, and from line and field rejects found and returned by the customer. A major portion of legitimate returns failed because of defects due to human mistakes. If these are eliminated, they do not have to be sorted out. Several illustrations show the successful application of this principle. (1) By substituting automatic control of cathode heating-wire insulation the variations in diameter are 1/10 what they were and productivity and reliability have been increased. (2) By relocating the winding machines for spade wound heaters, some handling was eliminated and the machine speed could be slowed down (fewer defects). One operator was responsible for more operations and pride in good workmanship was increased. (3) Semi-automatic production aids have been installed with good results. (Several pictures are shown.) (4) Automatic tube testing equipment was installed and it eliminated errors due to operator fatigue, etc. In the original paper, as orally presented, other slides were shown illustrating additional improvements.

REVIEW: There is little of measured reliability in this paper. The thesis of "make it better and eliminate having to inspect out the defects" is fine as far as it goes. There will probably always be a need to inspect the product to be sure that the presumed quality or reliability is actually there.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Impact of the Darnell report on new specifications for electronic parts

AUTHOR: Wm. H. von Alven, ARINC Research Corporation, Washington 6, D. C.

SOURCE: Proceedings 1961 Electronic Components Conference, San Francisco, California, pp. 5-1--5-17, May, 1961

PURPOSE: To examine some of the changes in specifications for electronic parts arising as a result of the Darnell report, together with associated changes in management techniques and contracting practices.

ABSTRACT: The more recent specifications for qualification approval of paper capacitors, film resistors, and transistors, resulting from the implementation of the recommendations in the Darnell report, call for much larger sample sizes than were required in the older specifications. Qualification-approval procedures now evaluate not only the design of a device, but also its reliability. To obtain a meaningful evaluation at a reasonable degree of confidence, large numbers of test samples, randomly selected from large production lots, are required.

Significant progress in terms of reliability assurance and failure rate "guarantees" has been made with the issuance of the newer specifications for capacitors, film resistors, and transistors. The use of lot tolerance percent defective (LTPD) concepts for both life-test and non-life-test requirements whenever sampling plans are used has been recommended by the Darnell report. The LTPD concept gives the customer a much clearer idea of how much protection he is receiving from a given sampling plan than when only the acceptable quality level (AQL) is specified.

The life test plans used in the capacitor specification MIL-C-14157B, the proposed film resistor specification, and in the newer specifications for semiconductor devices are described. The advantages of the latter over MIL-STD-105 plans are cited. Two other types of plans which may find increasing usage as lot-by-lot acceptance testing methods in new specifications for electronic parts are also described. Reference is made to the role of step-stress and accelerated life-test techniques in assessing the failure rate levels of electronic parts under normal use conditions. Some of the problems which remain to be solved are cited.

REVIEW: This paper presents an encouraging picture of the rate at which the recommendations of the Darnell report are being implemented, and of the interest with which the military services and the electronics industry are seeking solutions to the problems involved. The sources of many of the points made by the author are carefully documented in the list of 12 references given at the end of the paper.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the reliability of solid tantalum capacitors

AUTHOR: G. H. Didinger, Jr., Technical Director, Kemet Company, Union Carbide Corporation, Cleveland, Ohio

SOURCE: Proceedings 1961 Electronic Components Conference, San Francisco, California, pp. 6-1--6-20, May, 1961

PURPOSE: To report on an analysis of failure rates of solid tantalum capacitors.

ABSTRACT: The solid electrolytic tantalum capacitor, properly made and applied, is a reliable electronic component. Long term tests made on capacitors manufactured between 1957 and 1960 have shown mean times to catastrophic failure of more than five million hours when used as rated. Tests under accelerated conditions have shown reasonable correlation with the long term data. An acceptable approximation to the ordered failure distributions has been found graphically. It is therefore possible to obtain worthwhile information from properly run tests on small samples. The variation of mean life with temperature and voltage has been charted. This permits the use of acceleration factors of 1,000 or more with reasonable confidence. It also allows the prediction of the improvement in reliability which will result from derating the capacitors.

The statistical methods applicable to the life testing of capacitors are reviewed. The necessity and advantages of accelerated life tests when dealing with long-life items are noted. Various aspects of the determination of the mean life of solid tantalum capacitors by conventional and accelerated testing are discussed, and proposed objectives of further work are cited. Graphs are presented, depicting the results of actual tests.

REVIEW: Designers of electronic equipment should find the information in this paper helpful. The techniques and results will also be of interest to those concerned with the reliability testing of capacitors. While the statistical methods discussed are not new, they are presented here with emphasis on their relevance to the problem under consideration.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Non-destructive testing of electronic parts

AUTHORS: G. G. Brown and K. Greene, United States Testing Company, Inc., Hoboken, New Jersey

SOURCE: Proceedings 1961 Electronic Components Conference, San Francisco, California, pp. 7-1--7-10, May, 1961

PURPOSE: To outline and illustrate the principles of the non-destructive screening of electronic component parts.

ABSTRACT: Screening is a process for the improvement of in-circuit component part reliability by identification and removal of individual potentially weak parts, prior to their installation in equipment. Identification is obtained by the use of tests which employ environmental, electrical, and mechanical stresses, separately or in combination, to identify abnormal individual component parts by their anomalous behavior under stress. The stresses employed in screening are non-destructive. Anomalies most frequently consist of abnormal changes in selected sensitive parameters, or of qualitatively different responses.

The technique of screening on the basis of lot-by-lot distributional characteristics constitutes a relatively recent refinement of the screening process. The nature and advantages of this technique are discussed. Specific screening tests must be tailored to the application. Some modes of failure cannot be detected by non-destructive testing techniques, in which cases destructive testing on a sampling basis must be carried out.

The most critical factor in the conduct of a meaningful screening program is the design of the screening procedure. The most desirable approach is a complete evaluation program to determine the characteristics, modes of failure, and pattern of performance of the part being considered. Some of the methods of evaluation which can be used, singly or in combination, are step stress, test to failure, and accelerated life tests. The objective is to determine the parts' weak points and then to design a procedure to cull the potential failures non-destructively. When time is not available or funds are short, it is necessary to rely heavily on engineering experience in designing useful procedures. Examples are given of screening procedures for fixed film resistors, solid tantalum capacitors, and semi-conductors, to illustrate the principles discussed. Some possibilities for the expansion of understanding in this field are indicated.

REVIEW: This paper provides a useful outline of the principles involved in the design of non-destructive screening procedures for electronic component parts. As the authors have indicated, the specific procedure for any given purpose must be worked out to meet the needs of the situation.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An approach to life prediction of high-voltage components

AUTHORS: John P. Agrios, U.S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey and W. T. Starr, Engineering Laboratories, General Electric Company, Schenectady, New York

SOURCE: Proceedings 1961 Electronic Components Conference, San Francisco, California, pp. 8-1--8-14, May, 1961

PURPOSE: To describe a method for predicting the life of polyethylene insulated rf cables under conditions of high voltage stress.

ABSTRACT: Premature breakdown of insulations under high voltage stresses has been traced many times to ionization of voids within the component. To combat such failures, several methods have been used extensively over the years to determine the safe limits and approve the installation of such components in electronic equipments. Dielectric strength and corona extinction voltage have been the most popular means for achieving these goals. However, it has been determined that these methods, especially the former, do not necessarily provide data for long and reliable life for such components. In view of this, equipment engineers have been very cautious in utilizing these components at their maximum safe limits. Consequently, the components are being grossly underrated in order to attain long and reliable lives.

A study was recently completed on the life characteristics of radio frequency and pulse cables under high voltage conditions at frequencies of 60 cps to 10 kc, at a temperature of 24°C but not including conditions which would cause thermal breakdown. A method has been developed to measure the number of discharges emanating from such cables and to establish the correlation between such discharges and the life of the cables. It appears that the number of discharges per foot of cable to failure is constant and independent of the applied voltage and frequency of the applied voltage over the range from 1.0 to 2.5 times the discharge extinction voltage. Thus, by counting the number of discharges per second at 60 cps, a tool is available for predicting life behavior. It is believed that this work may serve as a basis for life prediction of other components under high voltage stresses. (Authors)

REVIEW: This paper is a discussion of various aspects of a method for predicting the life of a certain type of insulation under conditions of high voltage stress. As the authors point out, the principles involved may have potentially wider applicability than that indicated in the paper. The suggestion is made that when electrical discharges occur under high voltage stresses, the probable life of the component may be estimated by simply measuring the variation of discharges per second with voltage at 60 cps, and then measuring the life at one voltage at higher frequencies, if the tests are conducted at voltage-frequency combinations where breakdown due to thermal conditions does not occur.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Derating philosophy of Minuteman transistors

AUTHORS: J. W. Tarzwell and G. K. Cullers, Autonetics, Downey, California

SOURCE: Proceedings 1961 Electronic Components Conference, San Francisco, California, pp. 9-1--9-14, May, 1961

PURPOSE: To describe the development of a derating philosophy for Minuteman transistors.

ABSTRACT: The derating philosophy for transistors for the Minuteman program, as developed by Autonetics, was based on (1) previous component derating experience, (2) semiconductor manufacturing knowledge, and (3) available data. From the system Mean-Time-Between-Failure (MTBF) requirements an average failure rate goal was established for individual components. Manufacturers were requested to submit a program for attaining the required reliability goal. This program was to include the maximum recommended ratings, the parameter degradation to be expected over three years while operating at the recommended ratings, and a test program to verify these estimates, as well as a planned component improvement. The maximum ratings established were, in general, for voltage, current, junction temperature, and dissipation.

The manufacturers of transistors were asked to define the points which must be designed to such that degradation experienced would not affect the reliability. To allow for degradation it was either necessary to tighten initial limits or expand the commercial prototype limits. The manufacturers recommended that the design limits be loosened initial limits. This resulted in lower costs, but worked some hardships on design. It was generally agreed that reliability could be gained by reducing or limiting ratings to values lower than the ratings designed into the transistor. The manufacturers indicated that there should be a possible trade-off of ratings versus reliability.

The paper describes the combining of the information from manufacturers with other available data to obtain a set of recommended operating points for use by design engineers. Reference is made to a testing program by which manufacturers generated more detailed and specific information on their devices, for use in revising derating points and parameter limits. Illustrative graphs and tables are presented.

REVIEW: This paper contains information of interest to design engineers concerned with electronic equipment.

R E L I A B I L I T Y A B S T R A C T S
A N D T E C H N I C A L R E V I E W S

TITLE: Testing the insulation in electronic components with high-voltage direct current

AUTHOR: G. Leslie Hill, Hill Research Company, Oakland, California

SOURCE: Proceedings 1961 Electronic Components Conference, San Francisco, California, pp. 11-1--11-12, May, 1961

PURPOSE: To describe a method of testing the condition of insulation in electronic components using high-voltage direct current.

ABSTRACT: The most common method of testing the insulation in high-voltage apparatus has been to apply a high-voltage alternating current for a given period of time. Experience and research have shown that such tests can damage the insulation without the knowledge of the test engineer. Puncture of the insulation may occur at or near the end of the test period, or even after the test period, after the operator has started to reduce the alternating current voltage. The alternating current high-potential test provides no means of predicting the dielectric strength of the insulation without puncturing it.

This paper describes a high-voltage direct current method of forecasting the dielectric level of an insulation without destroying it. The method broadly comprises rectifying increasing increments of high-voltage alternating current to high-voltage direct current. The high-voltage direct current is then impressed on the insulation under test and, by means of a high-voltage voltmeter and a microammeter, the voltage applied and the current passing through the insulation are indicated for each increasing increment of impressed voltage. The measured values of the conduction current or the calculated values of megohms resistance are then plotted against the measured values of applied d.c. voltage to graphically determine the dielectric strength of the insulation before puncture. Various aspects of the method are described and several illustrative examples are cited.

REVIEW: The method described in this paper may be quite useful for testing the dielectric strength of the insulation in various types of electronic components. However, a word of caution concerning the application of the method seems to be called for. It appears from the description given that when d.c. micro-amps are plotted against d.c. kilovolts (e.g. as in Figures 2(a), 4, 5, 6, 7 and 8 in the paper), that extrapolation is used to obtain the far right portion of the graph, and that a tangent is then projected from a point on the extrapolated curve to the horizontal axis. The point of intersection with the horizontal axis is used in predicting the point of breakdown. It should be pointed out that this procedure can result in erroneous predictions, and that the errors become potentially more serious as the range of extrapolation is increased. It would therefore be desirable, in applying the method, to keep this range as short as possible.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dielectric testing and protection of high-voltage transformers in electronic circuits

AUTHOR: W. Wahlgren, Electro Engineering Works, San Leandro, California

SOURCE: Proceedings 1961 Electronic Components Conference, San Francisco, California, pp. 12-1--12-8, May, 1961

PURPOSE: To discuss some of the problems in the design and testing of transformers for electronics applications, and to make recommendations for improving the relevant testing and protection techniques.

ABSTRACT: In modern electronic equipment some transformers are required to operate reliably over a wide range of frequencies and at power levels into the megawatt class. This has posed insulation and testing problems which are not contemplated in the existing standards. This paper discusses the need to reappraise the points of emphasis in the design and testing of transformers used in these applications, and explains and discusses some of the paragraphs in the new AIEE proposed Standard for High Power Wideband Transformers. Various recommendations are made for improving the testing and protection techniques, for design evaluation, production testing, and maintenance purposes.

The following are among the principal points made. The primary windings of plate transformers are not well served by hipot-type testing but rather should be tested by over-excitation at suitable frequencies. When hipot testing is employed, the current as well as the voltage should be examined. Measuring the capacitance and dissipation factor of the transformer insulations can be very helpful in monitoring the condition of the insulation. The frequencies employed in hipot testing should be in the frequency spectrum of the transformer. The new proposed Standard for High Power Wideband Transformers is cited for dielectric testing. Wideband transformers offer many special problems in insulation design and testing and recommendations are made. Thermal heating of insulations is a very important aspect of the design and manufacture of wideband and high-frequency transformers, and tests to examine this matter should be included in the schedule. The value of testing at high frequencies as opposed to low frequencies is recommended for consideration.

REVIEW: This paper should be of interest to those concerned with the design of electronic equipment in which transformers are involved, and to those concerned with the manufacture and/or testing of transformers for use in electronic equipment. It serves a useful purpose as a discussion of problems related to transformer reliability, and makes recommendations regarding solutions to at least some of these.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Vitreous enamel capacitor development for high reliability and military applications

AUTHOR: A. S. Takacs, Vitramon Incorporated, Bridgeport, Connecticut

SOURCE: Proceedings 1961 Electronic Components Conference, San Francisco, California, pp. 26-1--26-12, May, 1961

PURPOSE: To describe the dev^lopment of a highly reliable capacitor.

ABSTRACT: Many techniques have been devised for increasing the reliability of various types of components. Each product has its own particular set of causes for failure, and the method of eliminating or reducing the failures also becomes distinct. "Burn-in" tests and derating are two examples. An approach in contrast to these is that of designing reliability into the component. This paper describes the steps taken by Vitramon Incorporated in designing reliability into the dielectric of its vitreous enamel capacitors.

A thorough study was made of the electro-chemical and physico-chemical properties of vitreous enamel dielectrics. The findings indicated the relationship of electrical parameter drift to eventual catastrophic failure. With the nature of catastrophic failures so identified, a dielectric formulation was reached which had tight atomic bonds and which displayed smaller interstitial holes. Some of the details related to tests on the new dielectric material, identified as "Frit 155," are quoted.

Testing to date has demonstrated, with 90% confidence, a failure rate of less than or equal to 0.0024 failures per 1000 hours under accelerated test conditions (125°C at 750 volts). Assuming an acceleration factor of 100 for this testing over rated operating conditions (125°C at 500 volts), this corresponds to a failure rate of 0.000024 per 1000 hours. A new test program will provide a minimum of six million component test hours per year.

Demonstration of extremely low failure rates, in the order of 10^{-7} per 1000 hours, are prohibitively expensive by the usual methods of life testing at rated conditions. Accordingly, an accelerated life test program has been set up for determining the 2000-hour capabilities of any lot of capacitors. It appears that this testing program will replace or at least supplement exhaustive long-term reliability testing.

REVIEW: This paper presents a brief description of the experience of one company in developing a highly reliable capacitor. This experience, and perhaps particularly the part related to accelerated testing, will be of interest to those concerned with the reliability testing of capacitors.

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

TITLE: The space environment and its effects on materials and component parts

AUTHORS: S. N. Lehr and V. J. Tronolone, Space Technology Laboratories, Inc., P. O. Box 95001, Los Angeles 45, California

SOURCE: Proceedings 1961 Electronic Components Conference, San Francisco, California, pp. 28-1--28-27, May, 1961

This paper is virtually the same as the one covered in Abstract and Review Serial Number 166.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Aerospace electronic materials--Applications/Environments/Effects

AUTHOR: Erik G. Linden, U.S. Army Signal Research & Development Laboratory, Fort Monmouth, New Jersey

SOURCE: Electro-Technology, vol. 68, December, 1961, pp. 125-131

PURPOSE: To summarize the properties of materials in the space environment.

ABSTRACT: The present view of the space environment is characterized by a vacuum of 10^{-8} mm Hg or less, intense solar radiation (including the far ultraviolet and X-rays) and the two Van Allen radiation belts. Materials are used either on an outer surface or in a protective enclosure. A list of materials for outer surface use is given and includes Kel-F, alumina, silicone rubber, fused-silica glass, epoxy glass-fiber honeycomb, aluminum paint, some epoxy paints, aluminum and stainless steel. The emissivities of each component must be carefully considered for temperature control by radiation. Inside an unpressurized enclosure many of the unplasticized plastics can be used. Most structural metals are satisfactory except that heated Mg, Cd, or Zn may have too high a vapor pressure. The fatigue and creep properties of materials are affected by the environment; some are better and others are worse in a vacuum. The lack of oxygen in space reduces or eliminates the bad effects of ultraviolet light on plastics. The solar X-rays do not degrade the electrical properties of polyethylene, alumina, polyester or epoxy glass-fiber laminates. The Van Allen belts may temporarily disrupt the electrical performance of many materials. Lubricants must be non-volatile, or they will not last long in high vacuum, and some which depend on a gas or vapor layer for effectiveness, e.g., graphite, are completely ineffective.

REVIEW: This article is an introduction to the subject and serves the purpose reasonably well. The subjects are treated in a way that provides considerable repetition. No mention is made of cosmic rays, either to give the effect or to say it is negligible.

An extensive bibliography is included, citing over 100 references. The reader interested in this topic may wish to refer also to Abstract and Review Serial Number 166.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The "rate of change factor" in reliability

AUTHOR: Phil Holden, Quality Assurance Department, Transistor Products Division, Texas Instruments Incorporated, Dallas, Texas

SOURCE: Electro-Technology, vol. 69, January, 1962, pp. 53-55

PURPOSE: To discuss the idea that rates of change of parameters with time or during tests may be more significant guides to component reliability than absolute deviations in parameters.

ABSTRACT: A natural practice in reliability studies is that of making initial measurements on the parameters of interest, subjecting the sample to the desired reliability tests, and then re-measuring the parameters. Plotting the distribution of these parameters before and after testing provides a good indication of what happened to the values during the test. It enables the calculation of probabilities that parameter values will lie within desired limits, and gives information about average parameter changes and similar quantities. However, it does not provide information as to the intrinsic reliability of individual components.

It is proposed in this paper that, instead of plotting the distributions of the parameters before and after testing, one should plot a single distribution of differences between the before and after values. This distribution reflects a change in parameter value per time interval, and accordingly is referred to as a "velocity distribution." In some cases it may be more advantageous to use the percent change or some other functional relationship rather than the velocity. The less change a parameter exhibits during a reliability test or actual operation, the more reliable the device. Therefore one would be interested in screening out those devices which exhibit changes of an abnormal amount. That is, ideally one would like to screen out those devices which produce a secondary mode, if any, in the velocity distribution, and to have left as a result only those devices which during operation will display a zero-centered velocity distribution with small dispersion. However, two problems complicate this in practice. One is that very large samples are required to locate a secondary mode and to describe its position and shape. The other problem is that the small number of units which deviate abnormally may display very wide dispersion. Several hypothetical examples are used for illustrative purposes and the advantages of using the velocity distribution are summarized.

REVIEW: The idea presented in this paper is potentially very worthwhile and should be tried in some specific cases to see how it works out. Its practical usefulness will of course be restricted to those cases in which sufficient data can be made available. Incidentally, the author's statement that a velocity distribution inferred from data was found to be exactly normal leads the reviewer to remark that a more cautious word than "exactly" would have been preferable.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability audits

AUTHOR: Richard R. Landers, Chief, Tapco Group Reliability Office, Thompson Ramo Wooldridge, Incorporated, Cleveland, Ohio

SOURCE: Machine Design, vol. 33, March 2, 1961, pp. 76-83

PURPOSE: To describe the use and advantages of a reliability-design audit.

ABSTRACT: Just as financial audits are made of a company's books, so should an audit be made of its engineering activities. The design-review generally has become a ritual and does not serve the purpose. The audit should be done, at specified stages in the design, by auditors who work nearby so that there is no feeling of outside interference. The delays caused by auditors should be less than one day. The auditor has a check list for a guide and he makes sample analyses for verification. He also reviews and lists pertinent failure data and field reports. His working papers are quite complete and can serve as records of the job. The auditor is more concerned with methods than with details since it is not his function to redesign. Where errors are disclosed, they should be handled carefully to avoid embarrassment. Specific recommendations should be the only output of the audit that is generally seen by others. At completion, the auditor issues a statement that the design was checked and was done in accordance with good practice; if necessary he lists the unacceptable practices. Standards are important in this work and, since they are usually neglected, this audit program can be an incentive to compile them and bring them up to date. Not all drawings are checked; some errors are missed in this way and it is an economic question of how complete the audit should be: the costs of uncaught mistakes vs. cost of catching them in the design stage. Even though engineers do not always accept the design audit at first, most of them are able to work with it when it has been properly explained and after they have had some experience with it.

REVIEW: Those who are responsible for design engineering may wish to read this paper. Whether or not it is a procedure already followed by many companies is not known. Many of the problems that design reviews have may also become associated with the design audits after they have been used for some time. The author seems to equate design-audit and reliability-audit. The word reliability is not defined and does not seem to have the same meaning, for example, that it has in electronics. There is some confusion as to what the auditor puts in writing, to whom he shows it, and who may find it in the files if he wants to look. There is also the question of whether the auditor works in parallel with the checker, or takes the output of the checker. Some comment is made about duplication between auditor and checker; it certainly seems that consideration would be given to combining the two functions.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fatigue in metal joints (two parts: 1--mechanical; 2--welded)

AUTHOR: Ralph G. Crum, Assistant Professor, Civil Engineering Department, Carnegie Institute of Technology, Pittsburgh, Pennsylvania

SOURCE: Machine Design, vol. 33, March 30, 1961, pp. 108-113 and April 13, 1961, pp. 176-178

PURPOSE: To show how to design metal joints for good fatigue life.

ABSTRACT: 1--Mechanical Joints: Failures are fatigue if the load is applied and removed more than once; therefore, most mechanical failures are fatigue. Static design is not necessarily good fatigue design. This article is concerned with loads that are relaxed (to zero) after each cycle. The cumulative effect of damage is not known exactly, but the linear theory is probably the best available. Notches or discontinuities in geometry or structure are prime initiators of fatigue cracks. Temperature corrections can be the same as for static loads. Corrosion can be serious at joints as can fretting (microscopic rubbing of parts). A lubricating coating of MoS_2 can reduce fretting fatigue significantly.

The theoretical stress concentration for an American Standard thread is 3.8 but the stress can vary with forming methods. The head-shank joint usually produces an even higher concentration. Some specific designs can reduce these effects. It is best to have the shank threaded more than necessary for the nut and the joints should be tightened to 75% of the ultimate strength of the material. Multiple fasteners introduce new problems (design curves are given for some groupings). Test results can be gleaned from the literature and given a common base in modified S-N curves (some are shown).

2--Welded Joints: These depend more on the skills of the designer and fabricator than does any other type of joint. Production results will probably not duplicate laboratory tests. The weld heat in spot welded joints does not affect all materials in the same way. Post-weld heat treatment is not beneficial to aluminum materials and may be detrimental to steels. High static strength of spot-welds tends to be accompanied by poor fatigue strength. Fusion welded joints are sensitive to the quality of the weld. Criteria for good welds are given. Curves show fatigue lives of several welding methods, welding qualities, and application severity. A list is also given of common causes of weld failures.

REVIEW: This is a very simplified account of fatigue properties. More complete elementary accounts are given in the references cited below. Some of the points such as linear cumulative damage are being debated rather heavily. No mention is made of fatigue notch factor as opposed to stress concentration nor of the extreme variation in fatigue life for specimens which are nominally the same.

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RELIABILITY ABSTRACTS
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These two articles are useful chiefly to bring the fatigue problem to the attention of the uninitiated. More complete references should then be consulted. The subject is still in a state of change and proper design tends to be more art than science.

REFERENCES: [1] Sines and Waisman: Metal Fatigue, McGraw-Hill, 1959
[2] Stulen, Cummings, and Schulte: Machine Design reprints, Preventing Fatigue Failures, 1961
[3] ASTM publications (various)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The value of reliability predictions in design

AUTHOR: Robert T. Williams, ARINC Research Corporation, Washington, D. C.

SOURCE: Machine Design, vol. 33, April 27, 1961, pp. 154-156

This paper is a condensation of the one covered in Abstract and Review Serial Number 126, and cites the latter as a reference.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The design of test equipment for high reliability product

AUTHOR: L. J. Paddison, Sandia Corporation, Albuquerque, New Mexico

SOURCE: 7 pp., in Transactions 11th Annual National Conference, Aircraft and Missile Division, American Society for Quality Control, Los Angeles, California, November, 1961

PURPOSE: To discuss some of the more important considerations in the design of test equipment for high reliability product.

ABSTRACT: The test equipment and techniques of data acquisition used in the testing of high reliability product must themselves be highly reliable. This fact presents a many-sided problem in the design of test equipment. The facets of this problem discussed in this paper are summarized by the author as follows.

1. The test equipment designer can, and should, influence the product test requirements to obtain the maximum uniformity, reliability and efficiency in data acquisition and reduction.
2. Automation of testing processes is our best answer today to the needs for fast and accurate data. In a substantial fraction of the cases studied, there is also a cost advantage through automation.
3. Standard circuits and modules offer significant advantages to reliability--and help avoid re-invention.
4. Component standardization is effective if succeeding orders are properly re-qualified. Derating practices, together with redundancy, where marginal conditions exist, are a must.
5. Error of Measurement studies, if performed at an early stage, can significantly reduce the possibility of making erroneous decisions on product.
6. A design review in two phases--first, before the design is committed, and secondly, when the equipment is ready for delivery--offers significant advantages.
7. Regular field reports provide the necessary confidence in the equipment, or identify areas where attention is needed.
8. Development reports provide important history on the design approach, but most important, they provide a self-audit for the designer.
9. Standardization of equipments or methods, though important to the reliability of the equipment, may result in stagnation of design effort. Hence, it is important that some fraction of the available development effort continually examine new components and new techniques to match them against new or existing testing problems.

REVIEW: The problem considered in this paper is encountered in reliability testing in many areas. The discussion should therefore prove to be rather generally helpful. In addition to the points covered in the paper, the author mentions some other important features of the problem. These include calibration and maintenance methods, modifications to meet changing requirements, and environmental considerations.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Product improvement through failure reporting

AUTHORS: Edson B. Gould III and Richard J. Rainwaters, Hughes Aircraft Company, Culver City, California

SOURCE: 36 pp., in Transactions 11th Annual National Conference, Aircraft and Missile Division, American Society for Quality Control, Los Angeles, California, November, 1961

PURPOSE: To discuss the fundamental technical and philosophical differences in data collection requirements for logistics, maintainability, and reliability on complex electronic systems.

ABSTRACT: There is a fundamental difference in purpose, procedure, and skill required to meaningfully report valid equipment failures with sufficient objectivity and detail to permit fruitful investigation as contrasted with reporting parts usage information for supply and logistics purposes. The requirements for a good failure reporting program to satisfactorily combine reliability, maintainability, and logistics purposes are discussed. The basic steps in the development of a failure reporting system are reviewed. The topics discussed include reliability improvement, equipment considerations, data user requirements, source capability, hardware flow diagram, maintenance form review, and machine processing.

The selection of a suitable failure reporting form on the basis of knowledge obtained from the above investigation is described through the use of samples of forms designed to satisfy specific functions. These include a development engineering form, a production reliability test form, and field report forms. The coding of input data, the analysis and reduction of data, and failure analysis and corrective action assurance are also considered.

REVIEW: This paper is a rather extensive discussion on the subject of failure reporting. As such, it will be of interest to those concerned with the setting up and/or operating of failure reporting systems to satisfy reliability, maintainability or logistics objectives.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Personnel subsystem reliability analysis

AUTHOR: Lynd J. Esch, Nortronics, A Division of Northrup Corporation, Hawthorne, California (present address: Astropower, Inc., Electronic Products Division, Costa Mesa, California)

SOURCE: 18 pp., in Transactions 11th Annual National Conference, Aircraft and Missile Division, American Society for Quality Control, Los Angeles, California, November, 1961

PURPOSE: To propose a program and methodology for increasing operational weapon system reliability by reduction of the incidence and the effect of human errors.

ABSTRACT: The human operator frequently contributes an element of critically low reliability to weapon system operation. Recent studies indicate that approximately one third of all equipment failures in a certain group of missile systems are initiated by human operator errors. This estimate may be rather low because of problems with malfunction reporting codes and human reticence to admit errors. Any technique or program which can significantly reduce the incidence of human error in the operation of a weapon system can make a significant contribution to the reliability of that system.

It is proposed that personnel subsystem functions be integrated into system reliability evaluations on the same basis as hardware functions. Figures of merit derived on this basis are illustrated and the importance of reliability values which include human functions is discussed with respect to design problems. Two methods of deriving human reliability values in advance of full simulation programs are discussed. The Early Estimation method is based on error rates for task elements as available in the literature. As more and better data become available, this method promises to become a significant design tool. The method of Discrete Element Simulation is based on part-task and element simulation, carried out under controlled conditions approximating those of the operational system. It is expected to be particularly effective in defining human reliability problem areas in the early research and design phases of system development, as well as in the evaluation of design alternatives.

REVIEW: In the published literature on human task performance there is very little suitably quantified information on human error frequencies. Thus little is available on the quantitative evaluation of the reliability of the human element in weapon systems. This paper is therefore concerned with an important problem which needs more attention than it has received. The ideas presented will be intrinsically useful and should also serve to stimulate further thought and research in the area of personnel subsystem reliability.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Simplified reliability mathematics and statistics

AUTHOR: Clifford M. Ryerson, Vice President, El-Tek Corporation, 13040 Cerise Avenue, Hawthorne, California

SOURCE: Design Guidelines for Air- and Spaceborne Electronics, Space/Aeronautics Technical Reference Series, December, 1961, pp. 16-19

PURPOSE: To give a simplified presentation of the basic mathematics and statistics used in reliability prediction.

ABSTRACT: This paper presents simple descriptions of some of the mathematical models used in reliability prediction. The binomial distribution is explained, and its use in reliability calculations is illustrated. The relationship between the exponential failure law and the Poisson distribution is shown and the relationship between the Poisson distribution and the binomial is mentioned. Illustrative examples of calculations involving the exponential and Poisson distributions are given. The use of the chi-squared distribution in calculating confidence limits on mean time before failure is illustrated. A table enabling simplified calculations of such confidence intervals is given. The paper also includes a table of values of the exponential function, a chart for use in dealing with cumulative probabilities from the Poisson distribution, and a table of percentage points of the chi-squared distribution. References to other pertinent tables are cited.

REVIEW: This is a tutorial paper which explains in a very simplified way some of the basic mathematics and statistics used in reliability prediction. Such a paper serves a useful purpose for those not familiar with these topics. While the material could also be obtained from various textbooks which are available, the presentation in this paper is specifically slanted towards reliability applications.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Component applications

AUTHOR: D. R. Earles, Reliability Engineer, The Martin Company, Denver, Colorado (present address: Research and Advanced Development Division, Avco Corporation, Wilmington, Massachusetts)

SOURCE: Design Guidelines for Air- and Spaceborne Electronics, Space/Aeronautics Technical Reference Series, December, 1961, pp. 69-129

PURPOSE: To provide a check list of points regarding applications of various electronic components.

ABSTRACT: This paper presents, in check list form, useful information and advice regarding applications of the components listed below.

Blowers	Meters
Capacitors	Motors
Choppers	Potentiometers
Circuit breakers	Relays
Clutches (magnetic)	Resistors
Coils	Resolvers
Connectors (standard)	Servos
Diodes	Suppressors
Electron tubes	Switches
Failure modes	Synchros
Generic failure-rate distributions	Timers
Gyros	Thermistors
Joints (solder)	Transformers
Lamps	Transistors
	Varactors
	Waveguides

A table summarizes the kinds of capacitors commonly manufactured to Mil specs and their normal applications. Another table gives representative relative costs of fixed resistors of comparable electric size. Also presented in tabular form are failure modes of electronic components and generic failure-rate distributions (upper extreme, mean, and lower extreme rates per million hours) of electronic components.

REVIEW: Many of the points listed in this presentation may well be familiar to the average design engineer. Nevertheless, he is likely to find it worthwhile to go over the list, as it constitutes a carefully prepared summary. Sources of the material used are given, permitting the reader to check further on points of interest to him.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A survey of techniques for analysis and prediction of equipment reliability

AUTHORS: H. E. Blanton, Raytheon Company, Lexington, Massachusetts and R. M. Jacobs, Sylvania Electric Products, Incorporated, Waltham, Massachusetts

SOURCE: 14 pp., presented at Northeast Electronics Research and Engineering Meeting (NEREM), Boston, Massachusetts, November, 1961; summarized in NEREM Record, pp. 41, 159

PURPOSE: To present a synopsis of representative techniques that are used in the analysis and prediction of equipment reliability during the design phase.

ABSTRACT: Reliability engineers are confronted with an ever-increasing number of techniques for analyzing and predicting equipment reliability. It has become apparent that a survey of these techniques, elaborating on recommended uses, distinguishing features, and sources of data, would prove valuable. This paper is an effort to present such a compendium of information. No attempt has been made to evaluate, recommend, or criticize the methods or techniques either by the sequence of the presentation or by the descriptive details. The authors invite communication for the purpose of maintaining the survey at current level.

Currently available techniques are classified in this paper according to application:

(a) prediction of circuit or module reliability when part reliability, circuit configuration, and internal and external stresses are given;

(b) prediction of equipment or systems reliability when module reliability, equipment diagram, and operational requirements are available;

(c) advanced mathematical/statistical techniques which supplement the preceding methods under certain prescribed conditions.

A few techniques which do not fall into these categories but which may prove valuable for specific applications are mentioned. The ways in which these various methods may be employed, as well as an indication of their validity, are examined.

A literature search reveals that although a few papers on reliability prediction appeared during the 1940's, the bulk of the material was published subsequent to that time. The bibliography given in the paper lists the papers cited in the text as well as others which may be of general interest. Also included are references to several edited bibliographies which may be consulted for information on additional papers. (Authors in part)

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

REVIEW: This is a very commendable piece of work. The task of providing a survey of techniques for reliability analysis and prediction, as the authors have described it, is a big undertaking. There is no doubt of the need for and usefulness of such a survey, and the effort merits the cooperation of all who have contributions to make in this area.

In a private communication the first author has indicated that the eight papers which were presented in the two Reliability Sessions at NEREM, November, 1961 (See Abstracts and Reviews Serial Numbers 191-198) have been published in their entirety in "Proceedings, Northeast Electronics Research and Engineering Meeting, Sessions 7 and 12, Reliability: A Design Criterion." Copies of these proceedings may be obtained at $5 each from the Institute of Radio Engineers, 313 Washington Street, Newton 58, Massachusetts. In addition, separate reprints of the paper covered in this review are available from either author.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design considerations for reliable electronic equipment

AUTHOR: W. J. West, Autonetics, Downey, California

SOURCE: NEREM Record, Northeast Electronics Research and Engineering Meeting, Boston, Massachusetts, p. 42, November, 1961

PURPOSE: To discuss design considerations for reliable electronic equipment, with specific reference to the Minuteman guidance and control system.

ABSTRACT: The design phase of an electronic equipment consists of four major steps: (1) mechanization decision, (2) derating, (3) circuit tolerance to parameter drift, and (4) electronic parts packaging. The decisions made when the system mechanization is established greatly affect the reliability level of the equipment. The mechanical decisions which were made for the Minuteman guidance and control system are listed.

The concept of derating in electronic circuitsis similar to that of safety factors used in mechanical systems. Stresses on electronic parts are voltage, current, power, temperature, vibration, shock, etc. Temperature and voltage are commonly used as stress parameters for derating curves. On the Minuteman system, derating curves have been determined for each part. For each circuit a failure rate budget was established and the designer was required to adjust the stresses in the circuit until the predicted failure rate of the circuit was less than the budget.

Circuits in the Minuteman system are designed to withstand part-parameter drift up to the three-year limits of deviation from nominal, which are between two and three times the initial incoming inspection limits of deviation from nominal. To assist the designers in evaluating circuits for tolerance to parameter drift, five analysis methods have been developed. They include worst case analysis, two types of parameter variation, moment method, and Monte Carlo method. The analysis by each of these methods is briefly described.

The last step in the design phase is the arrangement of packaging so that the heat dissipation is below a prescribed amount per square inch and the temperature of each part is below that specified by the circuit designer. The package must be able to withstand the vibration and shock requirements for the system.

REVIEW: This paper provides a useful discussion of considerations which have been found to be effective in designing reliable electronic equipment. Those who are interested in more detail than is given in the above paper may wish to refer to an Autonetics Report "Design Considerations for Reliable Electronic Equipment," by W. J. West and H. S. Scheffler, 40 pp., available from the authors.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Predicting the reliability of satellite systems

AUTHOR: R. H. Myers, Hughes Aircraft Company, Culver City, California

SOURCE: NEREM Record, Northeast Electronics Research and Engineering Meeting, Boston, Massachusetts, p. 43, November, 1961 (summary only; full text available from author)

PURPOSE: To describe the reliability prediction procedures peculiar to highly redundant satellite systems.

ABSTRACT: The cost of sustaining satellite systems become prohibitive unless exceptionally high levels of reliability are achieved. Small differences between predicted and actual satellite reliability can mean multimillion dollar operational losses due to the replacement satellites needed to sustain the system. This paper is concerned with the reliability prediction procedures peculiar to highly redundant satellite systems. Both standby and functional redundancy are considered.

In order to avoid prohibitive costs, there is a need for a 200 times improvement in average life between current airborne equipment and essentially the same equipment, circuits, and functions, when enclosed in an orbiting non-maintainable satellite. Such an improvement must come through the judicious use of redundancy. The redundancy may be on a joint, part, circuit, or equipment level and on a functional or standby basis. In functional redundancy, all redundant parts, circuits, and equipment are operating continuously, whereas in standby redundancy another item is switched on when a preceding one fails. The reliability gains made possible through the application of redundancy must be realistically predicted in order to establish criteria for weight, volume, performance versus reliability and total cost tradeoffs. The questions to be answered relate to how much redundancy to use, i.e., how many levels, and of what type(s). The latter appears to be controlled by engineering considerations while the former must be based on realistic predictions.

REVIEW: This paper will be of interest to designers of electronic systems employing redundancy. The examples of calculations, which were part of the oral presentation, were not reproduced in the NEREM Record, but are found in the full text of the paper, available from the author. The calculations are based on redundant and non-redundant versions of a typical bi-stable multivibrator circuit. The usual assumptions of exponentially distributed lives, constant failure rates, and independence are made in these calculations. In addition to the reliability predictions, certain engineering factors have strong bearing on the choice of types and levels of redundancy. A list of 17 key factors is given as a checklist for functional and sequential redundancy. At least some of the points in this checklist seem to be overlooked by many of those working with redundancy in electronic systems.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability and design of electronics systems and equipment

AUTHOR: F. Moskowitz, Laboratory for Electronics, Inc., Boston, Massachusetts

SOURCE: NEREM Record, Northeast Electronics Research and Engineering Meeting, Boston, Massachusetts, p. 44, November, 1961

PURPOSE: To discuss some of the tools and techniques available to the electronics circuit and systems designer for use in coping with reliability problems.

ABSTRACT: In recent years attempts have been made to understand the nature of equipment failure. This new understanding has made possible certain new techniques for solving reliability problems. Some of these techniques are discussed in this paper, viz. (1) component improvement, (2) failure prediction as a design tool, (3) design techniques for reliability, (4) measuring and monitoring reliability performance, (5) redundancy techniques, and (6) automatic maintenance and auto-diagnosis.

The appropriate reliability figure of merit for any equipment or system depends on the final use to which the equipment is to be put. New concepts in reliability must be evolved to meet the needs of new situations which develop. The systems designer must work with available components, but he should insist on high standards and on quantitative reliability figures of merit. Trying to improve the reliability of an old component usually is not worth the effort; the finding of new components to perform desired functions is generally a better approach.

The statistics of failure is important to the designer. He must be able to predict the distribution of the parameters of the components in his circuits, and the effects of various environmental factors on these parameters. He must understand the basic principles on which failure prediction techniques are based, and know where they are applicable.

REVIEW: The brevity of this paper and the generality of the discussion are such that little if any technical information of use to design engineers is conveyed. It may be that more was given in the oral presentation.

One statement in the paper does not seem plausible, perhaps due to a misprint. The statement is "... the system reliability increases exponentially with complexity,..." It would seem that the more complex the system, the greater the number of individual components, and hence the greater the probability of failure. One would therefore say that the probability of failure of the system tends to increase with complexity.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design reliability creation through management directives

AUTHOR: J. W. Griswold, The Boeing Company, Seattle, Washington

SOURCE: NEREM Record, Northeast Electronics Research and Engineering Meeting, Boston, Massachusetts, pp. 78-79, November, 1961

PURPOSE: To develop the theory that reliability control may be obtained through control of the effects of manufacturing variance, and to discuss the role of management directives in the achievement of design reliability.

ABSTRACT: In order to achieve high orders of reliability in complex products, it is necessary first to identify the activities that must be controlled. When the activities are identified, research into their contribution to the probability of failure can lead to improved control methods. By integrating the knowledge gained with direction from management authority, improved reliability can be achieved. An underlying cause of unreliability is manufacturing variance. It is a purpose of reliability research to provide knowledge of the nature and probability of this variance. The probability of failure is determined by the area common to the stress and strength distributions. This area may be reduced by (1) increasing the distance between the nominal values by reducing the stress or increasing the strength, or by (2) reducing the variation about the mean value of either or both of the stress and strength distributions. Each of these methods has advantages and disadvantages, and a proposal has been made that safety margins be established in terms of standard deviations. It should be the responsibility of the designer of the equipment to decide whether to increase the safety margin or reduce the variation in order to reduce the probability of failure. His decision must be based on the amount of information available and the stringency of the reliability requirement.

In order to achieve reliability, management must effectively control employee actions during those activities which have been identified as contributing to failure. Certain principles are listed as the background for a reliability program expressed by management directives. A sample list of titles of design reliability directives is given. Brief reference is made to design review procedures.

REVIEW: This paper will be of more interest to reliability managers than to design engineers. The relationship between the stress distribution, the strength distribution, and the probability of failure is the essential basis of derating philosophies. It is true that reduction of the variances of the two distributions will, other factors remaining the same, reduce the probability of failure. The importance of control through management direction as a factor in achieving this reduction of variances is emphasized. The principal contribution of the paper lies in the discussion of activities to be controlled and their role in design creation and design assurance.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The human as an element in system reliability

AUTHOR: J. Spiegel, The Mitre Corporation, Bedford, Massachusetts

SOURCE: NEREM Record, Northeast Electronics Research and Engineering Meeting, Boston, Massachusetts, pp. 80-81, November, 1961

PURPOSE: To discuss certain aspects of the problem of the human component in assessing the reliability of systems.

ABSTRACT: Most of the research which has been done on human factors in systems analysis has been concerned with limits of human tolerance to various environmental factors. Little work has been done on failure rates or distributions of times to failure for humans. In view of this lack of information, system reliability prediction based upon component failure rates, when human beings are included as components, does not seem to be feasible. However, the limits information which is available will provide the systems designer with some insights as to the probable effects of placing human beings in certain positions in systems.

One of the problems encountered in human reliability analysis is that of the large sample-to-sample variance found in studies of human behavior. It has been observed that the more macroscopic the behavior being sampled, the greater the variance among sample means tends to be. For example, the sample-to-sample variance in studies of man's interaction with his social environment is likely to be much greater than the sample-to-sample variance in studies of anatomical or physiological events. Four references are cited as sources of information on anatomical and physiological factors, but information on social interactive situations is not as readily available. One of the most important social interactive situations is that of communications among the human elements of a system. Reference is made to the "wheel" and "circle" types of communications networks, and to the undesirable effect of constrained communications.

REVIEW: This paper points up the need for research on the problem of failure rates for human components in systems. The lack of quantified information on human error frequencies seriously hinders reliability predictions for systems having human components. No doubt the variance problem cited by the author will present one of the most important difficulties. The reader interested in the problem of human component reliability should see also Abstract and Review Serial Number 188.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Maintainability and material support costs

AUTHOR: R. I. Moeller, IBM Space Guidance Center, Owego, New York

SOURCE: NEREM Record, Northeast Electronics Research and Engineering Meeting, Boston, Massachusetts, p. 82, November, 1961, and IBM report No. 61-907-404, 13 pp., November, 1961

PURPOSE: To examine the effect of package size and repair cycle time on the material support costs of maintaining an equipment in the military inventory.

ABSTRACT: The functional packaging concept is becoming increasingly popular in the design of electronic systems. With this concept, the equipment is so arranged that each physical package contains a discrete functional portion of the system. The advantage of this packaging approach is that troubleshooting is easier, and the equipment can be returned quickly to an operational condition by relatively inexperienced technicians. The failed package can be returned to a repair shop for servicing by experienced repairmen. However, the packaging approach has a disadvantage in the higher cost of the material support required.

This paper examines the relationship among material support costs, package size, and package repair time. A hypothetical equipment is assumed, and its pertinent characteristics are given. Two support concepts for the equipment are assumed: (1) on-the-spot repair by replacing the defective component, and (2) repair by replacing the package containing the defective component. In order to demonstrate the variability of cost, packages of various sizes are assumed, repair cycle times are varied, and the number of spares required to support the equipment under the several conditions is computed. The costs of these quantities are then determined, and the ratio of the cost under concept (1) to that under concept (2) is plotted against repair cycle time. The plots show that total material support costs increase considerably when concept (2) is used, and that this increase in cost is compounded when the assemblies require a long repair cycle time.

Total material support cost is only one of the inputs in decision-making regarding equipment configuration and packaging. Other factors which must be considered include available man-power, skill levels, test equipment and maintenance costs, and allowable down time.

REVIEW: The topic discussed in this paper will be of interest to designers of electronic equipment. As the author points out, material support cost is only one of the factors to be taken into account in the early stages of a development program, but it is an important consideration which often receives too little attention. A potential cost-saving consideration would seem to be that of designing equipment so that standardized packages serve in several pieces of gear.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Weapons system design and supportability--a function of failure prediction

AUTHOR: V. J. Taylor, USAF Headquarters, Washington, D. C.

SOURCE: NEREM Record, Northeast Electronics Research and Engineering Meeting, Boston, Massachusetts, p. 83, November, 1961

PURPOSE: To discuss the role of failure predictions in establishing the supportability of a weapon system.

ABSTRACT: Supportability of a weapon system is a vital factor in whether it is a reliable system. The summation of knowledge concerning failures, their frequency, identification, ease of repair or replacement, and availability of skilled personnel and technical data determines supportability on a practical and economical basis. There is therefore a demand for knowledge of the nature of failures that can be expected to occur and of the necessary resources to restore the end item to operational status. Rapidly changing systems preclude obtaining adequate experience on which to base timely logistic determinations.

Some possible solutions to this problem include testing under simulated environmental conditions, product improvement, and compilation of failure information on a continuing basis. However, in each of these cases information is obtained after-the-fact of failures. These after-the-fact approaches do not substitute for in-phase design deliberations which would have precluded the failure or predicted it. Supportability through maintainability must be designed into a weapon system; the repair characteristics must receive definite consideration by the designer. Current military specifications place emphasis on this point through requirements for maintainability. There is also a demand for a capability to predict with reasonable accuracy the nature of failures and support requirements. One of the most urgent needs is for methods of providing criteria describing the factors required in making failure predictions. These basic considerations must be formulated by the design engineer and communicated to the logistician. Industry must develop failure-predicting techniques for use with their systems, which will ensure that the services employing the systems can provide the logistic resources necessary to achieve the intended operational reliability.

REVIEW: This paper points out the need for failure-prediction techniques individually suited to particular weapons, and calls upon industry to provide them. The discussion is non-technical in nature and provides no information which would be directly helpful to design engineers.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Statistical independence in reliability equations

AUTHOR: A. M. Breipohl, Sandia Corporation, Albuquerque, New Mexico

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 1-6, January, 1962

PURPOSE: To show the relationship between physical independence (dependence) and statistical independence (dependence).

ABSTRACT: After some preliminary remarks concerning statistical independence, a two-component stress-strength failure model is presented. Under this model, causal or physical dependence is defined and several examples are given. The author states that for practical purposes physical dependence is sufficient for statistical dependence, but physical independence is not sufficient for statistical independence. The probability of a system failing (if both components fail) when under different but equally likely environments is the average probability of the system failing under all environments. It is not the probability of the first component failing times the probability of the second component failing. An approximate expression for the probability of a system failing is given, assuming that the two components are not causally related but see the same stress and the stress and strength of the two components are normally distributed. In this derivation it is shown that

$$[P(A)]^2 \leq P(F) \leq P(A),$$

where P(A) is the probability of one component failing and P(F) is the probability of both components failing.

REVIEW: The main point of this paper is that even though components in the same system are physically independent this does not mean that they are statistically independent, if there is more than one possible environment. The author has shown that this will be the case, for example, if there are two equally likely environments to which both components may be subjected. Therefore, reliability engineers should take this into account when they compute failure probabilities. The extent to which the possible environments differ will largely determine the degree of statistical dependence of the components. A point which perhaps should be emphasized is that within any one environment the two components are statistically independent if they are physically independent.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Truncation of sequential life tests

AUTHOR: T. L. Burnett, International Business Machines Corporation, Space Guidance Center, Owego, New York

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 7-13, January, 1962

PURPOSE: To report on a study for the purpose of determining whether the available truncations for sequential life tests can be reduced for certain decision functions, to derive a simple rule for the truncation points, and to evaluate the discrimination of the two test plans given in MIL-R-26667A (USAF) dated 2 June 1959.

ABSTRACT: An undesirable property of all sequential tests is that the amount of testing is not specified in advance. In applying these tests to Reliability Engineering, this property makes test planning and budgeting very difficult. Furthermore, for all possible values of the true parameter (θ), the greatest amount of testing is required in the zone of indifference.

This paper shows that for the exponential density function and for certain decision functions, the amount of testing can be truncated and the desired Type I and Type II risks secured. An IBM 7090 Data Processing System was used to evaluate points on the Operating Characteristics (OC) curve for the selected decision functions. This was done by taking a series of random walks through the decision space until an accept or reject barrier was crossed for various values of the true mean time to failure (MTF) (θ). The relative frequency with which the accept barriers were crossed gave the probability of acceptance for that particular value of θ. A table of truncation points is given for some decision functions frequently used in Reliability Engineering. These truncation points, while substantially less in both test time and number of malfunctions than those usually specified, maintain the desired Type I and Type II risks.

With minor modification, the same technique could be used for truncating sequential tests for parameters of other distributions. (Author)

REVIEW: This paper provides a worthwhile contribution to the methodology of sequential life testing, which will result in savings of testing effort, while maintaining desired levels of discrimination. The method is based essentially on taking as full advantage as possible of the leeway provided by the approximations used for the constants in the decision function.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: PERT-PEP reliability controls techniques simplified

AUTHOR: Harry G. Romig, Director of Quality Engineering, Leach Corporation, Los Angeles, California

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 24-31, January, 1962

PURPOSE: To describe the PERT-PEP System and to give an improvement and simplification of its mathematical developments.

ABSTRACT: The Program Evaluation and Review Techniques (PERT) system was developed by the Navy for use in the Special Projects group to monitor and control the Polaris Program. Slight modifications in these techniques by the Air Force resulted in the Program Evaluation Procedure (PEP) system. These techniques are briefly discussed, together with the mathematical background for the present system.

The use of these methods to strengthen the reliability programs for both simple and complex systems are outlined. A new mathematical approach is given for the theoretical development of these PERT-PEP systems which results in simplifying the relations by using a linear solution rather than the cubic relation now used. The latter, when required, is cumbersome and time-consuming for evaluations. The new mathematical basis has much merit due to its simplicity. Controls are as good, if not better, under the new approach. The usefulness of this tool in reliability programs is evaluated.

REVIEW: This paper will be of interest to those concerned with the PERT-PEP system, and with reliability programs to which this system could be applied. The principal results related to the proposed new mathematical approach are given, and the author expects to present more details in a later paper.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Sampling procedures and tables for life and reliability testing based on the Weibull distribution (hazard rate criterion)

AUTHORS: Henry P. Goode and John H. K. Kao, Department of Industrial and Engineering Administration, Sibley School of Mechanical Engineering, Cornell University, Ithaca, New York

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 37-58, January, 1962

PURPOSE: To outline an acceptance-sampling procedure and present tables of related sampling-inspection plans for the evaluation of lot quality in terms of the instantaneous failure rate.

ABSTRACT: The sampling-inspection procedure and tables of plans evaluate the lot in terms of the instantaneous failure rate or hazard rate at some specified time. These procedures and plans match and supplement those provided earlier by the same authors [1] for the evaluation of the lot in terms of mean life. To use the plans it is necessary to know the shape parameter and the location or threshold parameter of the Weibull distribution.

The acceptance sampling-inspection procedure is as follows:

(a) Select at random a sample of n items from the submitted lot.
(b) Place the selected items on life test for some specified period of time, T.
(c) Determine the number of items that fail during the period of time, T.
(d) Compare the number of items that fail with a specified acceptance number, c.
(e) If the number of sample items that fail is less than or equal to c, accept the lot; otherwise, reject the lot.

Under this procedure the probability of acceptance for a lot depends on the probability, p', of item life being less than the test truncation time, T. For applications for which the shape parameter of the Weibull is known and for which T is specified, p' is a function only of the hazard rate at time T. Hence the operating characteristics for any given plan depend only on T and the hazard rate at time T. It is noted that the operating characteristic curves become steeper as the magnitude of the acceptance number is increased rather than becoming steeper as the size of the sample is increased under the usual forms of sampling inspection.

Plans may also be obtained using average hazard rate as the criterion of life-quality. The plans based on average hazard rate are distribution free.

Many tables are provided to facilitate the selection of the plan which satisfies the desired criteria. Several examples are given to illustrate the use of the tables.

A discussion of the instantaneous and average hazard rate criteria appears in the appendix of the paper.

REFERENCE: [1] Goode, Henry P. and Kao, John H. K., "Sampling plans based on the Weibull distribution," Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 24-40, January, 1961 (See Abstract and Review Serial Number 46.)

REVIEW: Engineers and statisticians wishing to design or evaluate acceptance sampling plans for life testing should be familiar with the procedures and plans given in this paper. The procedure given is for attribute inspection when the lot quality of interest is simply the proportion or number defective rather than the reliability or item life. Numerous plans are available in the literature for sampling by attributes, by variables, and for various criteria of life quality. The many plans depend in varying degrees on the information concerning the life distribution. It will be necessary for one using these acceptance sampling plans to seek the plan which meets the proper criterion subject to cost considerations.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Screening for critical variables affecting reliability

AUTHOR: C. H. Li, General Instrument Corporation, Newark, New Jersey

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 59-61, January, 1962

PURPOSE: To describe a method for screening many factors to identify a few critical ones.

ABSTRACT: The principle of the proposed screening method consists of combining factors into groups of suitable size and making a single test on each of these groups. Any group containing only noncritical factors will be eliminated after the first series of screening tests, leaving a much smaller group of factors, including all the critical ones, for more detailed study. The process of grouping and group-testing may be repeated a number of times. The best number of series of tests, and the best group size in each test series for the smallest total number of tests have been computed under the following assumptions:

1. Of a very large number of factors to be screened, only a very small number are critical.
2. The critical factors have much greater effect than all the noncritical factors combined, or the interactions among factors.
3. The screening tests are fairly sensitive.

With these assumptions the following screening rules are reached:

1. The smallest number of tests N needed for a screening experiment on d factors in s series of tests is $N = s(dc^{s-1})^{1/s}$, where c is the number of critical factors.
2. For best efficiency, each series in an s-series experiment must have the same number of tests $n = N/s$.
3. The number of factors tested in combination on a single test model, in the s-series of tests must form a geometric series with a common ratio of $(d/c)^{1/s}$.

A justification of the screening method and an example are presented.

REVIEW: The proposed screening method is limited in its application by the assumptions imposed. Before a scientist or researcher utilizes this method he should be reasonably sure that the assumptions apply to his experimental situation. The method assumes that there is zero error variance, which is unrealistic. To assume that a single critical factor has a much greater effect than hundreds of noncritical factors and their interactions combined is an oversimplication of the real world. In a discussion of interactions the author states: "High order interactions, however, seldom exist and often are not very useful." Even if the first part of this statement were true, knowledge of the existence of interactions is not only useful but, if ignored, will affect the conclusions regarding critical factors.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Factorial experiments in reliability analyses

AUTHOR: C. L. Barron, Minneapolis-Honeywell, Ordnance Division, Hopkins, Minnesota

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 62-67, January, 1962

PURPOSE: To encourage engineers to utilize statistical techniques and designed experiments.

ABSTRACT: This paper presents a justification for utilizing factorial arrangements in preference to the more primitive haphazard selection of treatment combinations and the classical one-factor-at-a-time method. Full factorial plans are compared with fractional factorial plans and an example of a fractional factorial plan for subjecting a limited number of units to particular environments is discussed.

REVIEW: The author is to be commended for his insistence that industrial experiments should be planned and analysed using statistical techniques. The discussion of factorial arrangements is at a very elementary level and it should interest experimenters in the advisability of utilizing statistically designed experiments.

The unique application of factorial arrangements described in the paper is an oversimplification of a very complex problem. In this example, the treatment combinations determine the level at which each of six environments will be sequentially applied to the test units. When environments are applied in sequence the ordering of the sequence is very important unless the environments are independent. Although the author gave "some attention" to the ordering he did not attempt to determine the effect of the particular ordering actually used.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Statistical methods as design tools

AUTHOR: Edwin F. Grey, Eastern Contract Management Region, Olmsted Air Force Base, Pennsylvania

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 68-73, January, 1962

PURPOSE: To provide a non-mathematical introduction to some recent developments in statistical design which have a direct bearing on most engineering investigations.

ABSTRACT: A short description and example of Random Balance designs, Evolutionary Operation, standardization of test procedures, simulation and Monte Carlo techniques and tolerances for mating of parts is presented. Random Balance designs permit the testing of a great number of variables with "generally less than 50" runs. Evolutionary Operation is a continuous cyclic procedure involving the introduction of minor controlled changes in a manufacturing process and then analyzing the effects on the product after each change is made. Standardization of test procedures is emphasized in order that tests on the same product by several laboratories can be compared and evaluated. Monte Carlo techniques simulate a system in operation on an electronic computer and this simulated system can then be studied. The use of statistical methods such as control charts can be very helpful in specifying tolerances for mating of parts.

REVIEW: The short resumés of the statistical techniques presented in this paper are adequate to introduce engineers to these topics. However they are only an introduction and the techniques should not be used by people who do not have some statistical training. Most of the methods presented in this paper are based on restrictive underlying assumptions and yield poor results unless the assumptions are valid for the particular investigation to be undertaken. Special care should be taken when random balance designs are utilized. The results of random balance designs which the author states are "more easily understood by engineers" will often mislead the engineer. It is the graphical analysis that is easily understood and not the designs. The same graphical analysis can be used with highly fractionated factorial designs. An investigator who wishes to use random balance designs would do well to first read the discussion of these designs by several well known statisticians, in the reference given at the end of this review. Although statistical methods in conjunction with statistically planned experiments will extract from the data the maximum amount of information, no technique can extract information which is not generated by the data.

REFERENCE: "Discussion of the Papers of Messrs. Satterthwaite and Budne", W. J. Youden, Oscar Kempthorne, J. W. Tukey, G.E.P. Box, and J. S. Hunter, Technometrics, Vol. 1, No. 2, May 1959.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How RCA meets AGREE test requirements

AUTHOR: Paul Jay Goldin, Manager, Statistical Quality Control, Airborne Systems Division, Defense Electronic Products, Radio Corporation of America, Camden, New Jersey

SOURCE: Transactions Fifteenth Annual Convention, American Society for Quality Control, Philadelphia, Pennsylvania, pp. 199-208, June, 1961

PURPOSE: To discuss the implementation and follow-up required by RCA to meet AGREE requirements, and to provide a review of the results encountered during AGREE testing.

ABSTRACT: The requirements of the Air Force adaptation of AGREE reliability testing of hardware are briefly outlined. The extreme importance to the contractor of having his equipment pass the initial and monthly reliability tests is noted. The contractor needs to take positive steps prior to the reliability test to assure himself that the finished product will meet the AGREE requirements. In order to implement this, the already tight process control system of RCA was further reinforced. This process control system has three objectives, viz. (a) to push the debugging phase as far back in the assembly and test cycle as possible, (b) to reduce the influences of the human factor, and (c) to assure the customer and RCA that each system, whether it was subjected to the AGREE test or not, would meet the contractual MTBF.

The normal RCA Control of two years ago is compared with the controls now being used on all AGREE programs. An important step in the new program is that of conducting exhaustive environmentally stressed debugging tests at selected component, printed circuit, selected sub-assembly, and black box levels, as opposed to debugging tests under ambient bench test conditions on black boxes and systems. All suppliers who build major assemblies are required to burn-in their units for given periods of time under the same environmental conditions imposed on RCA built units. Another important step is that of tightly controlling assembly processes and methods; some of the controls are mentioned. The forms and procedures used in failure reporting and analysis are outlined. The results of AGREE testing of specific equipment are summarized, and a number of significant observations are listed.

REVIEW: This paper should be of interest and use to those concerned with AGREE reliability testing of electronic equipment. While relating the experience of one company, it makes clear a number of advantages which AGREE holds for the contractor. These include better contractor-customer relations and the incentive to upgrade process control systems with resultant subsequent advances in the state of the art.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability requirements in parts specifications

AUTHOR: Charles J. Brzezinski, Office of the Assistant Secretary of Defense (Installations and Logistics)

SOURCE: Transactions Fifteenth Annual Convention, American Society for Quality Control, Philadelphia, Pennsylvania, pp. 215-229, June, 1961

PURPOSE: To discuss the problem of developing a procedure for incorporating reliability assurance provisions into specifications for component parts.

ABSTRACT: Reliability is a requirement which is difficult to describe in a specification for a component part. During the past several years a great amount of effort has been expended on the problem of developing a reliability assurance provision that might be readily incorporated into the many existing part specifications. Of the many methods proposed for specifying reliability, only one offers a solution both to the problem of the very large sample sizes required for life testing and to the problem of applicability to specifications for a wide variety of products.

The reliability assurance provision discussed in this paper might be described as a multilevel reliability requirement inasmuch as it proposes to establish more than one level of quality and reliability in each specification. The primary purpose of this paper is to examine two problems related to the development of such a multilevel reliability requirement: (1) the problem of developing a life testing procedure which calls for reasonably small sample sizes and still is capable of not only disclosing the reliability level a part can be expected to meet but also assuring conformance to this level when so specified by the purchaser; and (2) the problem of fitting such a flexible testing procedure into the inherently inflexible quality assurance provisions of a component part specification.

A specification embodying a multilevel reliability requirement does not require periodic updating as the state of the art advances, since requirements pertaining to higher levels of performance are included in the specification and can be applied as soon as these higher levels are attained. Such flexibility helps both the manufacturer and the user of a part. The former can obtain recognition for significant improvement in the performance of his product, while the latter can determine without additional testing whether parts are being manufactured that have the performance characteristics he desires. (Author in part)

REVIEW: Those concerned with the problem of specifying reliability should find this paper helpful. The paper describes the various aspects of the multilevel reliability requirement in considerable detail, including illustrative calculations of critical failure rates based on stated assumptions. Five pertinent references are cited.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An adaptation of the MIL-STD-105B plans to reliability and life testing applications

AUTHORS: Henry P. Goode and John H. K. Kao, Department of Industrial and Engineering Administration, Sibley School of Mechanical Engineering, Cornell University, Ithaca, New York

SOURCE: Transactions Fifteenth Annual Convention, American Society for Quality Control, Philadelphia, Pennsylvania, pp. 245-259, June, 1961

PURPOSE: To present a working procedure, together with the necessary conversion ratios, for applying the MIL-STD-105B sampling plans to reliability and life-testing applications for which the Weibull model is appropriate.

ABSTRACT: This paper is an extension of the paper "Sampling plans based on the Weibull distribution," by the same authors appearing in Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pennsylvania, pp. 24-40, January, 1961. (See Abstract and Review Serial Number 46.) The extension consists primarily of the inclusion of tables to facilitate the application of the MIL-STD-105B attribute sampling inspection plans. The authors remind one of the fact that in using the MIL-STD-105B plans the risk level at the acceptable quality level (AQL) varies from 0.01 to 0.20 depending on the sample size. The tables of this paper are indexed by the AQL, shape parameter of the Weibull distribution, and sample size. Those of the previous paper are indexed by acceptance number, shape parameter, and the ratio of test time to mean life for which the probability of accepting the lot of items is 0.10.

REVIEW: This paper contains a set of tables to facilitate the use of the MIL-STD-105B plans; otherwise, it is based entirely on the results presented in the paper covered by Abstract and Review Serial Number 46. The comments of that review also apply here. The tables in this paper are based on a slightly different set of levels of the shape parameter of the Weibull distribution. The tables in the previous paper would be preferable for controlling the consumer's risk at 0.10 and the plans of this paper for controlling the producer's risk between 0.01 and 0.20.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Which road to satellite reliability

AUTHOR: Richard H. Myers, Manager, Reliability Assurance, Aerospace Group, Hughes Aircraft Company, Culver City, California

SOURCE: Transactions Fifteenth Annual Convention, American Society for Quality Control, Philadelphia, Pennsylvania, pp. 261-274, June, 1961

PURPOSE: To discuss the reliability requirements of satellite systems, and the means of satisfying these requirements.

ABSTRACT: Exceptionally high levels of reliability must be achieved in satellite equipment because of multimillion dollar costs per launch and the replacement satellites needed to keep the system operational. When satellite reliability requirements, based on operating costs, are compared with the best parts currently available, it is concluded that a 200 to 1 improvement in average life is required. Traditional test and fix means alone will not bridge this gap. Strong reliability emphasis is required in two complementary areas, viz. (a) a documented technical reliability approach concurrent with (not subsequent to) each stage of design and development, and (b) a related reliability program plan that provides the means of implementing the technical reliability approach.

In order to achieve satellite reliability levels of 40,000 hours mean time between failures the <u>technical reliability approach</u> must consider

(1) Part, circuit and/or equipment redundancy,
(2) Design application of parts well within electrical and thermal ratings,
(3) Minimum part ambient temperatures,
(4) Maximum use of qualified parts from approved vendors,
(5) Marginal checking of all circuits,
(6) Elimination of parts with known wear-out characteristics, and
(7) Redundant joints and connections.

Implementation of an effective satellite <u>reliability program plan</u> requires

(1) A full-time project reliability group for technical and programming purposes,
(2) Initial and continuing reliability comparisons of required versus predicted reliability,
(3) A specialized parts test program including screening, culling and "burn-in" techniques,
(4) Comparative vendor testing to establish the "best" source,
(5) Complete qualification of parts, units, and systems prior to orbital flight tests,

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(6) Increased quality control effort including the 100-percent application of non-destructive inspection and test methods,

(7) Improved monitoring of supplier reliability programs,

(8) Reduction of failure reporting, analysis, and correction cycle times during the critical design and development satellite phases, and

(9) Training seminars to promote project awareness of the satellite reliability programs' objectives, needs and methods. (Author in part)

REVIEW: This paper will be of interest to designers of satellite systems. A later paper by the same author (See Abstract and Review Serial Number 193) pursues the topic further by considering reliability prediction procedures for highly redundant satellite systems. Apart from some necessary overlap in the discussion of economic justification for increased reliability emphasis, the two papers appear to be complementary.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability Instrument Panel

AUTHOR: Frank M . Gryna, Jr., Quality and Reliability Division, The Martin Company, Baltimore 3, Maryland

SOURCE: Transactions Fifteenth Annual Convention, American Society for Quality Control, Philadelphia, Pennsylvania, pp. 275-282, June, 1961

PURPOSE: To review the basic elements of reliability planning and control and to present a measurement technique for control.

ABSTRACT: Cnntinuous control of product reliability requires measurement--both of achieved product reliability and of task performance. In order to achieve control of a manufacturing process, it is necessary that the following conditions be satisfied:

1. The program must be defined.
2. Performance must be measured and evaluated against the standard.
3. A means for taking corrective action must be available.
4. Personnel must be motivated to meet the standards of performance established for their task.

These conditions are briefly discussed.

The author proposes a Reliability Instrument Panel as a means of measuring and reporting the performance of (a) product reliability and (b) performance of key functional tasks in the program. The Reliability Instrument Panel is essentially a listing of results for a number of indices representing tasks that directly or indirectly affect product reliability. Some of the key points to be considered in setting up this device are discussed. These include the development of adequate performance indices, the development of numerical standards of performance, and the reporting of the effect of poor reliability performance on schedules and costs. An illustrative example of the format of a Reliability Instrument Panel is given.

REVIEW: The ideas presented in this paper relate to reliability management rather than to the technical aspects of reliability measurement or prediction. A device for providing a continuous picture of performance on the tasks in a reliability program is certainly worthwhile. While the specific details will have to be worked out to meet the needs of any particular situation, the discussion in this paper should be quite helpful.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Myths and realities in reliability

AUTHOR: C. M. Ryerson, Product Assurance Administrator, Radio Corporation of America, Camden, New Jersey (present address: Vice President, El-Tek Corporation, 13040 Cerise Avenue, Hawthorne, California)

SOURCE: Transactions Fifteenth Annual Convention, American Society for Quality Control, Philadelphia, Pennsylvania, pp. 283-300, June, 1961

PURPOSE: To consider some common "myths" about reliability and discuss some clarifying facts.

ABSTRACT: Many existing concepts about reliability are either unrealistic or incomplete. There is usually an element of truth in each, but a framework of myth is frequently established around it which misleads the hearer or reader. Sometimes meaning of words is the basis for the myth. Other times conclusions are drawn on inadequate evidence or based on statements withdrawn from context.

This paper considers several of the common myths in turn and discusses some clarifying facts. (Author)

REVIEW: If in fact the ideas referred to by the author as "myths" are widely held by those concerned with reliability, then this paper may serve a potentially useful purpose. It contains no engineering or statistics, and is addressed essentially to a management audience. Some of the material presented is found also in the paper "Reliability from the program manager's standpoint," by the same author in <u>Proceedings Seventh National Symposium on Reliability and Quality Control in Electronics</u>, Philadelphia, Pennsylvania, pp. 169-181, January, 1961. No reference to the earlier paper is cited.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electronic reliability--a mechanical problem

AUTHOR: Howard I. Dwyer, Jr., Manager, Quality Control, Cincinnati Division, The Bendix Corporation, Cincinnati, Ohio

SOURCE: Transactions Fifteenth Annual Convention, American Society for Quality Control, Philadelphia, Pennsylvania, pp. 301-306, June, 1961

PURPOSE: To present a mechanically-oriented look at the reliability of electronic equipment.

ABSTRACT: When an electronically-oriented person looks at a complex equipment, he is likely to visualize it as a system of circuit elements and signals. He will then probably consider the nature of these elements and their electrical characteristics. The mechanical design engineer, on the other hand, will picture a collection of cabinets, racks, and chassis, and will consider how to hold them in place. These and other possible viewpoints are partially correct; each is limited in some fashion. In this paper, a piece of equipment is considered as a complex structure serving a structural purpose, with a view to exploring the possible contributions of a structural approach to equipment reliability. While structural integrity is not the only criterion for equipment reliability, reliable operation is impossible when elements fail structurally. The basic premise adopted is that most, if not all, electrical equipment failures are the results of mechanical breakdowns.

The structural aspects of electronic systems are described. Some of the conditions which promote electrical failure as a secondary effect of a primary mechanical failure are explored. The following are among the principal points brought out in the discussion:

(a) Designs and processes in assembly and handling should, insofar as possible, preclude a failure due to human factors.

(b) Adequate means of mechanical protection should be provided to prevent overstressing of electrical parts by various environmental factors.

(c) More attention than at present should be given to the strength, rigidity, and durability of main equipment support.

(d) The relationship between applied loads and component failures should be explored more fully.

(e) A compartmented approach in design reviews should be avoided.

A mechanically-oriented definition of reliability is proposed. The merits of the definition are discussed and illustrated.

REVIEW: As the author points out, the idea that an electrical part is a mechanically stressed member as well as a functional circuit element may be new to some and old to others. Some may not fully agree that most, if not all, failures in electronic equipment are the results of mechanical breakdowns. Nevertheless, the paper is a worthwhile discussion of the subject, and should serve to stimulate thought on the mechanical aspects of failures.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Optimization of equipment effectiveness

AUTHOR: Anthony Drummond, ARINC Research Corporation, Washington, D. C.

SOURCE: Transactions Fifteenth Annual Convention, American Society for Quality Control, Philadelphia, Pennsylvania, pp. 307-313, June, 1961

PURPOSE: To discuss the optimization of equipment effectiveness, with particular reference to the role of maintainability prediction.

ABSTRACT: Under Air Force auspices, ARINC Research Corporation has been engaged in a program directed towards developing techniques for gaining maximum product value in the specific area of airborne electronic equipment. Equipment value is considered to encompass the factors of effectiveness, requirements on the broader system, development time, and cost. Effectiveness is a measure of the equipment's ability to fulfill the requirements of the job for which it is purchased. Requirements on the broader system include such characteristics as weight, volume, and power requirements, which tax the supporting environment. Development time may well enhance the value, at least of a consumer product, by allowing its marketing ahead of the product of a competitor; a short development time for military equipment may be the essence of its value to the defense structure of the Nation. The cost factor may be interpreted in terms of the dollars and cents for initial production and subsequent maintenance, although it may sometimes be necessary to extend this concept to include other items. The aim of the program is to develop techniques for quantifying, measuring, and understanding the elements of the four factors, leading to tradeoff functions to serve as bases for early policy and design decisions.

The essential components in the factor of effectiveness are reliability and maintainability. Ultimate value maximization in terms of this factor is effected through the development of techniques for reliability and maintainability prediction. Whereas reliability prediction is well established in practice, maintainability prediction is still a curiosity. It is noted that a reliability prediction is of little value without information on the failure rates and the procedure by which the prediction was generated. An example shows that maintainability not only has its direct influence on availability but has a secondary influence by way of its effect upon reliability. This is due to the aspect of imperfect maintenance and is accounted for in the prediction technique developed and used by ARINC. The approach to the development of this maintainability prediction technique is briefly described. It is proposed to use a multiple linear regression model to relate the time required to perform an elemental maintenance activity to the values quantifying the physical or circumstantial characteristics of the unit or activity. Of the four factors affecting equipment value, it is considered that effectiveness offers the greatest and most time-consuming problems to be solved. The other three factors are believed to be more

receptive to treatment by adaptations of established methods.

REVIEW: This paper is a rather brief description of the approach taken by one company to the problem of optimizing equipment effectiveness. The introduction of more illustrative material, if such were available, would have been helpful to the reader. The conclusion regarding imperfect maintenance is both interesting and important, as is the discussion of the reasons for imperfections in maintenance.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Short cut statistical methods as applied to certain reliability problems

AUTHOR: Gordon H. Beckhart, Missile and Surface Radar Department, Radio Corporation of America, Moorestown, New Jersey

SOURCE: Transactions Fifteenth Annual Convention, American Society for Quality Control, Philadelphia, Pennsylvania, pp. 425-435, June, 1961

PURPOSE: To describe short cut statistical methods for solving certain reliability problems, and to illustrate their applicability.

ABSTRACT: The achievement of reliability in the production of complex electronic equipment is often hampered by shortages of time, effort, and money for the longevity testing of parts. In such cases, selection methods must be streamlined. In using short cut statistical methods, one must first determine what attributes of a part are desirable and then conduct tests which will determine with a given risk that the best source or supplier of the parts has been selected. After some introductory remarks on the general problem of reliability achievement, the author presents a discussion of six statistical methods, two for each of (a) selecting the best population based on percent defective, (b) comparisons of percent defective, and (c) assessing the representativeness of samples and selecting the population with the best median. The methods for (a) and (b) are based on [1]; sample sizes for obtaining representative samples are based on [2], and the selection of a population with best median is based on [3]. The necessary tables are reproduced and illustrative examples are given.

REFERENCES:
[1] S. S. Gupta, M. J. Huyett, M. Sobel: "Selection and Ranking Problems with Binomial Population", Transactions of 1957 National Convention of the American Society for Quality Control, p. 635.
[2] M. Sobel and M. J. Huyett, "Nonparametric Definition of the Representativeness of a Sample - with Tables", Bell System Technical Journal, Vol. 37, No. 1 January 1958, pp. 135-161.
[3] M. Sobel and M. J. Huyett, "On the Sample Size Required for Certain Statistical Problems in Reliability Studies", Proceedings of 2nd Annual Statistical Engineering Symposium, Army Chemical Center, Maryland, April 1956, p. 104.

REVIEW: This paper in effect calls attention to the methods available in the indicated references. Those wishing more detail on the methods and their underlying assumptions should refer to the original papers. It should be noted that while these methods are quite appropriate for the purposes intended by the original authors, their application does not, in itself, provide assurance of reliability. That is to say, for example, that the selection of a best available vendor or source does not necessarily imply that a desired degree of reliability will be found in the parts thus procured.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Progress in Department of Defense reliability programs

AUTHOR: Irving B. Altman, Office of the Assistant Secretary of Defense, Washington, D. C.

SOURCE: Industrial Quality Control, vol. 18, March, 1962, pp. 10-15 (presented at the Cornell University Seminars in Industrial Engineering, June 15, 1961)

PURPOSE: To summarize the development and publication by the Department of Defense of sampling standards for quality and reliability testing, and to indicate the progress of programs for quantifying reliability requirements.

ABSTRACT: The increasing complexity and cost of weapons systems and the destructive nature of missiles tests have focused attention on the need for attaining high levels of reliability at reasonable cost. Quantitative reliability requirements are appearing in contractual documents on an increasing scale. The specification of these requirements in meaningful statistical and engineering terms is one problem. Another problem is that of prescribing contractually the sampling and testing procedures and acceptability criteria to be used in demonstrating conformance to the reliability requirement. Modern statistical sampling techniques play an important part in this area. This paper reports on the development and publication by the Department of Defense of sampling standards for quality control and reliability testing, and on the progress of programs for quantifying reliability requirements and demonstration of achievement in contracts and specifications.

A summary is given of the Department of Defense program for developing and publishing a comprehensive series of statistical sampling standards for quality control and reliability testing. These applied mathematical procedures have been the fruits of over eleven years of joint research supported by the Department of Defense activities. Many of the sampling procedures have been used extensively in both Government and industry. Specific reference is made to Military Standard 105, Military Standard 414, the Dodge and Torrey continuous sampling plans, Department of Defense Handbooks H106, H107, and H108, and to sampling plans for reliability testing based on the Weibull distribution. Significant developments and progress in Department of Defense reliability programs are discussed. Reference is made to recent publications issued by the Office of the Secretary of Defense, the Army, the Navy, and the Air Force.

REVIEW: This is a useful summary of Department of Defense reliability programs, publications, and developments. Reasonably enough, the references to the individual items are quite brief. For those who wish more detail, some 31 references are cited. The value of the paper lies in the picture which it presents of the orientation of the separate items in the overall program.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The measurement and specification of product 'abilities

AUTHORS: J. A. Cafaro and H. D. Voegtlen, RCA Service Company, A Division of Radio Corporation of America, Riverton, New Jersey

SOURCE: Industrial Quality Control, vol. 18, March, 1962, pp. 20-26

This paper is virtually identical to the one which was published in the book "Research and Development Reliability," pp. 244-261, although it does not cite the earlier paper as a reference. The latter was covered in Abstract and Review Serial Number 25.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Variation research--the science of forcing defects to reveal themselves

AUTHOR: Dorian Shainin, Vice President, Director of Statistical Engineering, Rath and Strong, Inc., Boston, Massachusetts

SOURCE: Electronic Design, vol. 9, September 27, 1961, pp. 60-65

PURPOSE: To describe and illustrate the technique of variation research in pinpointing key factors affecting product quality and reliability.

ABSTRACT: The tracking down of factors affecting product quality can be a long, tedious, and frustrating assignment. Conventionally the experimenter sets certain factors at constant values and observes the effects of one other factor at a time. Statistical engineering involves the simultaneous consideration of many (all, if necessary) of the possible reasons for product malfunction. Many of the possible causes in large groups can be directly adjudged as irrelevant after a short period of gathering key data; this permits concentrated efforts to be applied to the few remaining possibilities.

It is reasoned that every effect has one or more causes, that generally a relatively few causes have a controlling influence on the effect, and that causes and effects vary. If the variation of an effect is properly studied, it can lead to the single cause (or combination of causes) of that effect. The study should be made by dissecting the group of all possible causes into subgroups, and eliminating those subgroups associated with trivial variability, then dissecting the remainder into further subgroups, and repeating the elimination procedure. The final result is the identification of the one or more causes of the effects under study. At the same time, information is often obtained regarding ways to control the effects.

The approach is illustrated by means of two case studies. The first involves the use of a 2 x 2 Latin Square in solving a problem in the manufacture of a complex pneumatic unit. The second relates to an application of a 2^3 factorial design in an analysis of two production lines. The basic rules for applying the variation research technique, and the advantages of using statistically designed experiments are listed.

REVIEW: The basic point made in this paper is that by analyzing the variations in effects by appropriate statistical techniques, factors affecting product quality can be revealed. While the idea is not novel, it is perhaps worth emphasizing. The two examples, which are oversimplified for the purpose of a clearer introduction, serve as good illustrations of the procedure.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Interpreting MIL Specs for system reliability

AUTHOR: Anthony J. Finocchi, Director of Reliability Engineering, ITT Federal Laboratories, Nutley, New Jersey

SOURCE: Electronic Products Magazine, vol. 4, February, 1962, pp. 26-30

PURPOSE: To advise engineering contractors as to how they are affected in time, money, and manpower by the specifications in military, space, and regulatory agency contracts.

ABSTRACT: To assure system reliability, specifications in contracts with governmental agencies detail technical performance and procedures--from manufacturing to shipping. These specifications require a considerable investment in time, money, and manpower. When a choice must be made between "time and money" and "reliability and quality," the latter factors usually suffer. The basis of a good reliability program is a thorough understanding of contractual specifications, and the requirements and constraints which they impose, before bids are placed. This awareness will tend to minimize the short-cuts in methods and materials which are the major hazards to reliability and quality.

There are many reasons for the lack of appreciation of the details contained in the numerous documents referenced in contractual agreements. These reasons include the fact that there are so many specifications--some 25,000,all of which may be in effect in any one contract as a result of cross-indexing and subreferencing. The language used is often difficult and ponderous, and the descriptions lengthy and involved. The contractor often concludes that a particular set of contracted specifications are to unrealistic, binding, and impossible to follow in the given time scale and in many cases can be waived anyhow--so why bother.

The importance of rigorous definitions is noted. The terms "breadboard," "engineering model," "engineering field or test model," "field service model," and "prototype or preproduction" are explained. The matter of coordinated specifications between agencies is briefly discussed. The format of technical specifications is described. The importance of taking careful note of the list of applicable documents in a contract is emphasized. General specifications are discussed, and four major general specifications are listed.

REVIEW: This paper is the first of a series dealing with specifications, the later articles in the series to appear in future issues of Electronic Products Magazine. The problem of clearly understanding the constraints imposed by specifications is clearly very important to contractors. This paper and others in the proposed series will no doubt serve a useful purpose in helping to clarify this problem.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability factors in thermoelectric generator design

AUTHORS: M. R. Seiler and T. S. Shilliday, Battelle Memorial Institute, Columbus, Ohio

SOURCE: Proceedings of the IRE, vol. 49, pp. 1952-1953, December, 1961 (letter to editor)

PURPOSE: To analyze the best way of arranging multiple thermoelectric elements.

ABSTRACT: The number of thermoelectric generating elements that can reasonably be put in series is limited by their failure rate (failure is assumed to be an open circuit). Several of these series groups (subsystems) can be put in parallel for more power. If the failures of the individual units follow the customary exponential law, the number of elements in series can easily be related to the fraction of subsystems expected to survive a particular period. The assumption is made that the system is loaded, always, for maximum power transfer. The relationships are then derived between mean-time-to-failure-of-simple-units, the expected fraction of system power available after T hours, and the maximum number of series elements. The maximum time to failure of the units is taken as 10^8 hours, the same as for good carbon composition resistors. A table is given which shows the results of the calculations.

REVIEW: This is a "rough and ready" calculation designed to give a "ball-park" idea of reliability problems. The results are, of course, dependent on the particular assumptions that are made. The short excursion into the binomial distribution seems to be without real purpose. It begins with mention of the "most probable" value and ends with the expected value. The result of the expected value derivation is the standard one which is also the result one intuitively expects from the original definition of binomial probability.

The numbers are interesting and those who have not had occasion to see or make a similar calculation should read this note.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: USAF to tighten AGREE test standards

AUTHOR: Philip J. Klass, Avionics Editor

SOURCE: Aviation Week and Space Technology, vol. 76, January 29, 1962, pp. 73, 77

PURPOSE: To report on plans by the USAF to tighten up on AGREE reliability test procedures as a result of field test experience.

ABSTRACT: This is a report on a presentation made at the Eighth National Symposium on Reliability and Quality Control by Griffith W. Lindsay, Air Force Systems Command Avionics Division, Wright-Patterson AFB, Ohio. The presentation dealt with changes in AGREE test specifications adopted or recommended by the Air Force as a result of a year of controlled field tests of the AN/ARN-21C Tacan sets. When these sets were installed on McDonnell F-101 aircraft in three Air Defense Command squadrons, it was expected that they would equal or exceed the near 150 hour mean-time-between-failures (MTBF) exhibited in factory tests at Hoffman Electronics Corporation. Instead, they have exhibited an over-all MTBF of only 63 hours. The principal sources of failures were (a) excessive tube filament voltage, attributed to improper setting because of limited availability of proper field test equipment, and (b) silicon diode crystal mixer failures. The latter had occurred also at the manufacturer's plant, where they had been classified as "secondary failures," resulting from other basic malfunctions. Under the existing AGREE test specifications the manufacturer was not required to substitute an improved diode, so long as the equipment met the specified MTBF.

As a result of this experience the Air Force has recently changed its standard contract form to require contractors working to AGREE specifications to take corrective action on all faults which exhibit a pronounced failure pattern, regardless of whether the equipment meets the specified MTBF without such action. It was indicated that new provisions must be established in the selection of samples of equipment to meet contractual MTBF requirements under AGREE tests. There is a need to make the AGREE test conditions more representative of actual field conditions. Design considerations which allow for difficulties occasioned by personnel handling are also important. Brief reference is made to favorable preliminary field experience with the AN/ARR-60 data link, built by Radio Corporation of America.

REVIEW: This paper gives a valuable indication of how field test experience can point up ways in which AGREE type reliability testing can be made more effective. Noted at the end of the paper is the fact that a new basic training film on AGREE reliability testing has been prepared by Radio Corporation of America under Air Force contract. The film, entitled "AGREE in Action," is available to defense contractors from the Air Force Film Training Center, 8900 South Broadway, St. Louis, Missouri.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Redundancy utilized to boost reliability

AUTHOR: Philip J. Klass, Avionics Editor

SOURCE: Aviation Week and Space Technology, vol. 76, February 5, 1962, pp. 72, 73, 75

PURPOSE: To describe some new redundant logic techniques which promise a major boost in avionics reliability in space and defense equipment.

ABSTRACT: Although the concept of redundancy is not in itself new, it has only recently become feasible for space- and weight-limited uses as a result of microelectronic construction techniques. This article reports on the application,at General Electric's Advanced Electronics Center in Ithaca, New York, of new redundant logic techniques to space and military equipment with the expectation of increasing reliability by a factor of 100 or more.

The technique being developed for use with digital (pulse) circuits employs three parallel channels, any one of which could perform the required function if redundancy were not desired. The three parallel channels are interconnected at suitable junctures to take a "majority vote" to determine the presence or absence of pulses at any instant. If a malfunction has occurred in one channel, the other two will carry the "vote" to produce a correct result. By dividing each of the parallel channels into a large number of segments and taking a majority vote after each segment, it is possible for the system to experience a sizable number of faults in all three channels and still perform satisfactorily, providing the faults do not occur simultaneously in identical segments of two out of the three channels. The number of such segments, or points of taking a vote, is referred to as the "level of voting." A chart depicts the reliability gains made possible through the use of parallel channel majority vote redundancy, and the improvement with increased voting levels. In the more sophisticated applications reliability is further enhanced through the use of redundant majority voting elements, one for each channel.

A device used by General Electric to demonstrate the relative immunity of majority voting redundant logic techniques to individual component failures is described. It is pointed out that redundancy is not a substitute for good circuit design or the use of good quality components, but is rather an additional technique for boosting reliability when the best components and circuit design are not adequate to meet operating requirements.

REVIEW: This article is a qualitative description of majority voting redundancy, and serves a useful purpose in conveying an impression of its possibilities without becoming deeply involved in its technical aspects.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dangers in safety systems

AUTHOR: E. P. Epler, Instrumentation and Controls Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee

SOURCE: Proceedings of the Joint Nuclear Instrumentation Symposium, co-sponsored by AIEE, ISA, IRE-PGI and IRE-PGNS, Raleigh, North Carolina, pp. 51-55, September, 1961

PURPOSE: To point out potential dangers in nuclear reactor safety systems.

ABSTRACT: An examination of nuclear reactor and critical assembly operation during the past twenty years shows that accidents were made possible because of the inadequacy of the safety system at the time of need. In some cases the safety system has increased in severity or even initiated the power excursion. Failures of safety systems are treated in three categories: (1) safety rods, (2) instruments, sensors and amplifiers, and (3) systematic failures. Included in category (1) are the relatively minor startup accident, sticking of control and safety rods, the possible piston action of rods which extend through the pressure vessel, and relative motion of the reactor core and control rod drive mechanism. Category (2) consists of the electronic portion of the system which can fail in a passive manner. Reliability is increased by two-fold and three-fold redundancy of channels. To minimize false trips and to permit testing of a single channel during reactor operation, coincidence of two or more channels is often required to actuate a trip. Systematic failures (3) are those in which the monitoring system or testing procedures are unable to disclose the difficulty, such as the case in which the safety system, automatic control system, and manual control system become coupled and all receive the same erroneous information. This situation exists when the safety system and automatic control system share the same ionization chambers. Even if separate chambers are used, inadvertent coupling may result from (a) leakage of water into adjacent shielding material, (b) introducing boron in the shield tank, containing the chambers, and (c) supplying the chambers from a common nitrogen supply that might possibly be wet. The discussion of failures is supported by a description of actual reactor accidents.

REVIEW: The author, who is one of the most knowledgeable men in the United States on reactor safety systems, has presented an interesting qualitative discussion of pertinent factors which must be considered in the design of adequate safety systems. These factors are based in part on a study of former reactor accidents. This paper should be read by all those responsible for existing safety systems and by designers of future systems. Existing systems should be reviewed to determine if any of the potential situations discussed in this paper are present.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Factors affecting design and sale of transistorized instrumentation

AUTHOR: E. B. Hubbard, Product Planner, Nuclear Electronic Products Section, Atomic Power Equipment Department, General Electric Company, San Jose, California

SOURCE: Proceedings of the Joint Nuclear Instrumentation Symposium, co-sponsored by AIEE, ISA, IRE-PGI and IRE-PGNS, Raleigh, North Carolina, pp. 127-129, September, 1961

PURPOSE: To compare qualitatively the relative merits of transistors and tubes for nuclear reactor instrumentation.

ABSTRACT: In comparing transistors with tubes, it is pointed out that transistors and their associated circuitry (a) are smaller, have lower mass and lower power requirements, (b) have limitations in high voltage and high frequency operations (primarily cost), (c) can withstand severe shock and vibration, but are less able to withstand voltage surges, (d) provide less unit isolation, (e) provide d.c. amplification down to 10^{-8} amp in comparison with 10^{-13} for tubes, (e) are more susceptible to radiation damage, (f) have relatively low upper temperature limits with performance dependent sharply on temperature, (g) are generally more expensive than tubes (10-15 per cent) for an equivalent function, (h) are perhaps generally more reliable, (i) are usually more difficult to service, (j) are excellent switches for trip and logic functions, and (k) permit pulse detectors to operate with much longer cable lengths. One should regard transistors and tubes as complementary rather than competitive for all applications in order to obtain the maximum advantages of each. However, because (1) there has been a popular tendency to "transistorize" everything during the last decade, (2) transistors are generally believed to be more reliable, and (3) experience with transistorized reactor control systems has been satisfactory, the customers prefer and hence are offered all-solid-state systems even though in some applications tubes are more desirable from the engineering design viewpoint.

REVIEW: Of interest to reliability engineers is the discussion on the mean time to failure for transistors and tubes. The author cites values ranging up to 2000 years which were obtained from, say, a 2500-hour test on 1000 units. One is cautioned against using data for reliability predictions beyond the 2500-hour test period owing to the fact that the failure rate may be increased by the onset of other mechanisms. The reviewer feels that the author has made a fair assessment of the relative merits of transistors and tubes. However, his attributing the customer's preference for transistor systems almost exclusively to a current "fad" for such systems (by implication) is subject to dispute.

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R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

TITLE: Accelerated aging of semiconductors

AUTHORS: B. T. Howard and G. A. Dodson

SOURCE: Bell Laboratories Record, vol. 40, pp. 8-11, January, 1962

This paper is a qualitative discussion of accelerated aging of semiconductors. The main points covered are essentially the same as those in an earlier paper by the same authors, covered by Abstract and Review Serial Number 165. Both papers are useful and informative discussions of the subject; the earlier paper goes more deeply into its technical aspects.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A probabilistic model for reliability estimation for space system analysis

AUTHORS: Landis S. Gephart and William Wolman, National Aeronautics and Space Administration, Washington 25, D. C.

SOURCE: Bulletin de l'Institut International de Statistique, 33[e] Session, Paris, 1961, 76, 11 pp.

PURPOSE: To develop techniques for indirect estimation of system reliability.

ABSTRACT: The authors point out that, in applications to space systems, there is usually insufficient data to estimate reliability from the results of large numbers of tests of the system under actual operating conditions. This arises since the systems of interest are relatively few in number. Thus indirect techniques are necessary to evaluate system reliability and these must be based on information from environmental tests of subsystems and components. The system considered is assumed to operate in different modes in each of k time periods, which together comprise the whole mission time. S_i is defined to be the event that the system operates successfully from the start of the mission until the end of the i th time period. Formulae are given expressing S_i in terms of more elementary events, for example the events S_j^* that there is successful operation during the j th time period ($j = 1, \ldots, i$). S_j^* is in turn written in terms of events P_{jk} ($k = 1, \ldots, \ell_j$) representing ℓ_j successful paths for the j th time period. The probability of the event S_i is expressed in various ways, for example in terms of joint probabilities of S_{i-1} and P_{ij}, $j = 1, \ldots, \ell_i$. An example is given in which the formulae are applied to a system consisting of two subsystems, which is required to operate in different modes in each of two time periods.

REVIEW: This paper carefully explains basic concepts in the calculation of the reliability of any complex system from knowledge of the reliabilities of its subsystems, components, and parts. Use is made of elementary laws of probability in deriving expressions for the reliability of the system as a function of the probabilities of the successful operation of paths and components during distinct time periods. Standard mathematical techniques are employed to provide a useful foundation for the analysis of complex systems, and in describing the basic philosophy involved in dealing with such systems. Important and difficult questions which remain to be solved include the estimation of the probabilities of successful operation of the paths and components, and the allowing for uncertainties in these estimates.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Recent developments in life testing

AUTHOR: Benjamin Epstein, Consultant, Palo Alto, California

SOURCE: Bulletin de l'Institut International de Statistique, 33^{e} Session, Paris, 1961, 85, 6 pp.

PURPOSE: To review the accomplishments in statistical methodology for life testing and to indicate some of the current and future problems.

ABSTRACT: The past decade has seen the intensive development of a statistical methodology for the design and analysis of life tests. This is of basic importance in reliability considerations, since the reliability of a system depends on the life distributions of components, taken either individually or in combinations. This paper gives a brief account of what has been accomplished in this area and indicates some of the current and future problems.

A recent bibliography on life testing, containing more than 600 titles of papers and books, provides a listing which includes the basic material in this field. A considerable amount of work has been done in the case where the underlying distribution of life is exponential. References to this work are cited. References are also cited to work in the following areas:

(a) two sample life tests,
(b) tests for departures from the exponential assumption,
(c) estimation based on a two-parameter exponential distribution,
(d) estimation based on truncated or censored data,
(e) estimation based on a mixed exponential distribution,
(f) methods of analysis based on the Gamma distribution,
(g) life test methods based on the Weibull distribution,
(h) non-parametric and distribution-free tests, and
(i) accelerated life tests.

Listed as problems which require further investigation are the following:

1. The design of life tests which are in some sense most economical.
2. The estimation of system reliability from data on components.
3. Studies of the effects, on decisions or estimates, of departures from basic assumptions.
4. Investigation of stochastic models for length of life associated with non-homogeneous Poisson processes.

REVIEW: This is a brief resumé of the literature on life testing and related topics prepared by one of the major contributors to that literature. It should be of considerable interest and value to anyone interested in this field. Some 41 references are cited.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Simulating tests of a system from tests of its components

AUTHORS: W. S. Connor and W. T. Wells, Research Triangle Institute

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 14-16, January, 1962

PURPOSE: To evaluate reliability of systems composed of several independent components connected in series, from reliability tests on each of the components.

ABSTRACT: The authors propose to simulate system outcomes by random selection of component test results. Since the components are arranged in series, the system outcome is a success only if each component selected is a success. Two system outcomes are disjoint only if they do not contain the same outcome for any component. Sets of disjoint system outcomes having specified numbers of system successes are considered. Each set consists of n^* simulated systems where n^* is the minimum number of samples tested for any component.

Formulas are given for evaluating the relative frequency of sets containing 0, 1, 2, etc. system successes. For a set containing x system successes the system reliability estimate would be x/n^* and confidence limits could be assigned by standard binomial methods using sample size n^*. The over-all reliability estimate is the weighted average of all possible values of x/n^*, the weights being the relative frequency with which each occurs. The result is equivalent to that obtained by using the product of component reliability estimates. Two suggestions are made for putting a confidence interval on the over-all reliability: (1) a weighted average of the binomial confidence intervals on x/n^* and (2) an interval of fixed length whose confidence coefficient would be obtained by a weighted average of the confidence probability appropriate to each value of x/n^*. In either case the weights are the relative frequencies of the various system sets. A simple numerical example is given.

REVIEW: The main contribution of the paper seems to be the development of the formulas for the relative frequency of simulated system sets with various values of x/n^*.

The authors have made the paper unnecessarily difficult to read by referring to "system outcomes" when they mean "sets of system outcomes." The formulas in the text refer to the number of such sets, not to the number of system outcomes. The idea of simulating systems from outcomes on components as well as the methods used for constructing confidence intervals are not new (See Abstract and Review Serial Number 152). No justification is given for the methods used in obtaining confidence intervals. The authors admit that they are unable to make the customary probability statement about these intervals.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analysis testing for improved circuit reliability

AUTHOR: Bruce J. Grinnell, International Business Machines Corporation, Space Guidance Center, Owego, New York

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 103-109, January, 1962

PURPOSE: To show a method for testing circuits, at the development stage, to uncover hidden weaknesses.

ABSTRACT: Component parts used in development work are rarely representative of the range of production parts. Several methods of circuit analysis were studied to see which would be the most effective in determining the behaviour of the circuit with production parts. The method chosen is a modification of "marginal testing" by N. H. Taylor. Each circuit is fabricated on a plug-in board with easily removable and adjustable components. Power supplies are similar to those in the equipment; input signals and loading simulate worst-case conditions. With the circuit operating normally, the electrical stresses are measured, compared with design values and any significant differences are resolved with the designer. The measured stresses are listed and the methods of achieving component value variation are listed for several components. Variation is stopped when either predetermined component or performance limits are reached. There are two sets of performance limits. Any circuit in its most critical application must meet the more broad ones. The tight limits parallel closely the initial design requirements. Some examples are given of the application of this method to circuits. Many groups in the company profitably use the results of this analysis and the costs are modest compared to the necessary redesign at a later stage.

REVIEW: The article is rather explicit on the methods used for analysis. They and the philosophy behind them seem very good. Possibly some groups might incorporate a portion of this analysis testing in the original design work.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Mathematical analysis of redundant systems--solving the problem with matrix algebra

AUTHOR: George D. Weinstock, ITT, Nutley, New Jersey

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 142-147, January, 1962

PURPOSE: To show that present methods employed to compute the probability of success for a redundant combination of modules are insufficient and to present a new approach using matrix algebra.

ABSTRACT: This paper considers simple and multistage redundant systems where repair is impossible. Each component (block) of the system is considered to have an exponential life distribution. The blocks are independent but not mutually exclusive. A lemma is presented which shows that if two or more blocks are combined in parallel or series parallel, the probability distribution of the system is not exponential, even though the lives of the blocks are exponentially distributed. The MTBF is derived for a simple redundant system and stated for a simple series-parallel system. The final section of the paper uses the results obtained in the first part of the paper plus simple matrix multiplication to present the probability of success of the system in a compact but complex form for any redundant-multistage system. The MTBF is also presented in a compact form.

REVIEW: The stated purpose of this paper seems to imply that by the use of matrix algebra a gap in the computation techniques for the probability of success and MTBF for multistage systems will be filled. A more modest purpose is that by the use of matrix algebra the probability of success of the system can be put in a complex form which the author states readily lends itself to digital computer programming.

In equation 21 the symbol det is used. It is assumed that this stands for the determinant of a matrix. Since the matrix is a 1 x 1, the det symbol is not needed. This is true for the equations 22, 23, 24, 28, and 29. In equations 22, 24, and 29 an equality sign is used where approximate equality should be indicated.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The life distribution and reliability of electromechanical parts of an inertial guidance system

AUTHORS: L. A. Weaver and M. P. Smith, Minneapolis-Honeywell Aeronautical Division, St. Petersburg, Florida

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 148-155, January, 1962

PURPOSE: To report on a study of electromechanical components undertaken to develop a mathematical model descriptive of the behavior of gyros in an inertial guidance system.

ABSTRACT: Studies have tended to show that the reliability behavior of inertial components, unlike that of electronic equipment, is not that of a simple first-order system. Experience on early inertial guidance systems has indicated that electromechanical parts such as gyros do not tend to follow the exponential law. This paper contains samples of analyses of two sets of data which illustrate the applicability of a mixed Weibull distribution. The first example involves a very tightly controlled life test consisting of 46 gyro spin motors. The second example relates to an actual application of gyros in a current inertial guidance system. The tests are described and the results are presented in tabular and graphical form. A comparison is made of the exponential and Weibull distributions relative to their suitability as models for these sets of data.

REVIEW: The results presented in this paper will be of interest to reliability engineers concerned with electromechanical systems. The conclusion that the mixed Weibull distribution provides a more suitable model for such systems than does the exponential seems to be well supported by the data. No doubt further investigations will be made, to broaden the basis on which the determination of a suitable mathematical model to describe the failure history of electromechanical devices may be made.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Nuclear protective system design for reliability

AUTHORS: V. S. Underkoffler, J. L. Cockrell, and J. H. Magee, Leeds and Northrup Company, North Wales, Pennsylvania

SOURCE: Proceedings of the Joint Nuclear Instrumentation Symposium, co-sponsored by AIEE, ISA, IRE-PGI and IRE-PGNS, Raleigh, North Carolina, pp. 130-148, September, 1961

PURPOSE: To present system design concepts for reliability enhancement and building blocks for their realization.

ABSTRACT: An electronic instrumentation system must satisfy operational specifications and perform with adequate reliability. This paper shows how one can quantitatively treat the reliability problem and how system modifications affect reliability. Primary attention is given to switching circuit problems associated with nuclear reactor protective systems, although the discussion of reliability is applicable to other instrumentation systems. Probability theory is applied to (a) a single component system, (b) a series (cascaded) arrangement of components, and (c) a parallel (redundant) arrangement in which (1) system failure does not occur until all components have failed or (2) operation is satisfactory only when a majority of the components have the proper output (voting redundancy or majority logic). In each case relationships are obtained between component failure rate (assumed constant), redundancy, repair of components and the ultimate effect of these factors on system reliability and mean life. The commonly used "two out of three" redundant protective system is treated in detail and numerical calculations illustrate how the mean life can be greatly improved when the mean time for component repair is reduced. Mean lives of some multichannel systems employing several components per channel can be increased by a factor of ten by using a scanning technique in which a single functional unit is switched sequentially from channel to channel. Described next are building blocks designed so as to permit their use in simple or complex nuclear reactor protective systems and so that testing of components for failures can be accomplished. Pulse testing procedures for the switching circuits are discussed.

REVIEW: The formulation of the coupled differential equations and their solution (with Laplace transformation) for reliability and mean life are presented in sufficient detail and clarity to enable any engineer to apply the quantitative concept of reliability to systems of the above-mentioned types. The numerical examples are well chosen for comparing the relative reliability of alternative schemes for accomplishing similar functions. The fact that the functional blocks and testing methods are in operation enhances the value of their description. Typographical errors noted are: p. 133, col. 2, line 3, instead of "$P_2(t)2\lambda\Delta t$",

read "$P_1(t) 2\lambda\Delta t$"; p. 145, 3/4 down, col. 1, instead of "$R(t) = K_1 e^{-s_1 t} + K_2 e^{-s_2 t} + K_3 e^{-s_3 t}$", read "$R(t) = K_1 e^{s_1 t} + K_2 e^{s_2 t} + K_3 e^{s_3 t}$". Also, in Appendix 2, the reviewer suggests use of the relation $s_1 = 2\lambda^2/s_2$ to avoid the loss of four significant figures in s_1.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some remarks on optimum reliability testing for space systems

AUTHOR: Catherine Dryden Hock, National Aeronautics and Space Administration, Washington, D. C.

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 110-116, January, 1962

PURPOSE: To discuss some of the problems in proving satellite reliability and to suggest a less conventional method of analysis.

ABSTRACT: As an example, suppose a satellite must have a functional reliability of 0.90 at a 90% confidence level for three months in orbit. The reliability must be proved by tests. If the conventional exponential assumption is made and standard tables are used (reference given), two units would need to last about 35 months or 20 units about three and 1/4 months. (Other necessary assumptions are made and optimum plans are selected.) If, instead, a group of satellites are tested for three months with no failures, the number in the test group can be calculated and is 22. Under the proper conditions, the two tests can be shown to be quite similar. Since they involve too much testing, one might try testing the components. If two unlike components are in series, a calculated upper bound shows that the required testing is more than doubled (although this bound is not the least upper bound). If these components are in a certain series-parallel arrangement, the number of components to be tested is quite small compared to the original results. It is emphasized that the value of paralleling circuits to save component testing is not generally recognized. The analysis becomes difficult if the circuits are complex. A general approach is given, using a probability model of the system as a function of component probabilities. A "Monte Carlo" technique is used to obtain the distribution of the system probability. Some points in this approach need more investigating. At least one complete physical system must be checked, if only to test the mathematical model.

REVIEW: The first part of the paper is a conventional treatment of reliability testing. In the section on series-parallel components, no mention is made of the fact that the savings in testing are probably largely (or solely) due to the decreased reliability requirements of the components because of the redundancy involved. The upper bound which was derived for series components seems too high, as suggested in the paper. The least upper bound may be no higher than that for testing the system itself. The author correctly comments that the suggested method provides an estimate of a tolerance limit, rather than a confidence limit, for system reliability based on component test results, and that further investigation will be necessary to establish the properties of this estimate. (For papers on the confidence limit topic see Abstracts and Reviews Serial Numbers 152 and 227.)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure analysis

AUTHOR: E. W. Kimball, The Martin Company, Orlando, Florida

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 117-128, January, 1962

PURPOSE: To show that analysis of failed parts is necessary for high reliability.

ABSTRACT: The thesis of this paper is that reliability can best be improved by exhaustive laboratory analysis of failed hardware. Attention is drawn to the various problems which arise in detecting the exact cause of malfunction. Unrealistic laboratory procedures are discussed and methods are proposed to obtain all necessary engineering data. Slides of disassembled parts are presented to illustrate how to "ferret out" difficult failure modes. The advantages of submitting assemblies to the laboratory for trouble shooting are described. Techniques for component dissection without causing additional damage to the failed parts are explored. Procedures for duplicating failures in the laboratory are examined. Illustrations are made of the benefits of laboratory evaluation by specialists well versed in discovering the ways in which hardware may fail. A development philosophy of "fix it--don't change it" is suggested. The ways in which proper reporting can facilitate corrective action are also shown. The conclusion makes the point that a comprehensive failure analysis effort is essential for developing successful missile systems. (Author)

REVIEW: Even though the author's points are made rather emphatically, there is little in the paper that would really be controversial. The one point, "fix it--don't change it," has validity depending on the seriousness of the flaw and where in the program it occurs. The several examples are good.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimating guided missile system reliability from R & D systems firing tests

AUTHOR: Al Steinberg, Army Rocket and Guided Missile Agency, Redstone Arsenal, Alabama

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 129-134, January, 1962

PURPOSE: To describe the method used by ARGMA to estimate the system reliability of guided missiles from firing test results.

ABSTRACT: Under the ARGMA method of scorekeeping, all systems tests are graded as success, failure, or no test. A success is defined as the achievement of the objectives of the tactical weapon, or as success of the primary test objective if the system is incomplete. Incomplete systems are weighted depending on the importance of subsystems to the mission. A system reliability trend line based on a 20 round moving average is plotted after 20 test results are available. Figures 1, 2, and Table I illustrate the mechanics of computing reliability for the purpose of depicting trends.

From the histograms plotted of ARGMA missiles, the following conclusions are evident:

a. The ultimate system reliability is achieved during development (curve levels off).

b. Production rounds are never significantly better than R&D rounds.

c. Design changes result in significant change in the reliability trend.

d. Systems firing tests are no substitutes for laboratory qualification tests.

e. Failures are generally random. (Author)

REVIEW: This paper describes the methodology and results found in a report distributed internally at ARGMA. The report is described by the author as "controversial from many viewpoints." The paper appears to be a reasonable explanation and justification of the system described. At least some of the material presented is found also in the report covered by Abstract and Review Serial Number 109.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The mathematics of reliability

AUTHOR: Clifford M. Ryerson, Vice President, El-Tek Corporation, 13040 Cerise Avenue, Hawthorne, California

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 163-176, January, 1962

PURPOSE: To explain some of the more useful mathematical concepts and charts and how to use them in reliability work.

ABSTRACT: This paper discusses elementary mathematical and statistical concepts and their relation to reliability work. The topics covered are indicated by the following section headings of the paper.

1) Probability in Reliability
2) Bernoulli Trials
3) The Binomial Distribution
4) Central Limit Theorem
5) The Normal Distribution
6) Degrees of Freedom
7) Cumulative Probability
8) Relating the Exponential and Poisson Distributions
9) The Exponential Failure Law
10) The Poisson Distribution
11) Cumulative Poisson Probabilities
12) Use of Molina's Tables
13) Confidence Limits
14) Confidence in Reliability Life Tests
15) Typical Reliability Test
16) Chi-Square Distribution
17) Use of Chi-Square Tables

Useful charts and tables for the Exponential Failure Law, Poisson Probabilities, Percentage Points of the Chi-Square Distribution and Upper and Lower Confidence Limits are given in the Appendix.

REVIEW: This is a tutorial paper which explains some of the basic mathematics and statistics useful in reliability prediction. Much of the material of an earlier paper by the same author (See Abstract and Review Serial Number 189) is contained in the present paper, which is the more extensive of the two. Although the material is available in various textbooks, the presentation is slanted toward reliability applications. Before using the results in this paper, one should consult a good text, especially in the case of confidence limits and the use of the Poisson distribution.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The CAMESA reliability test program

AUTHOR: A. P. Harris, Canadian Military Electronics Standards Agency, Ottawa, Ontario, Canada

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 185-195, January, 1962

PURPOSE: To summarize the Canadian Military Electronics Standards Agency reliability program.

ABSTRACT: The Canadian Armed Services have chosen U.S. designed electronic equipment for their operational needs and are therefore faced with the same requirements for reliable parts. To measure the reliability of Canadian produced electronic parts the Canadian Military Electronics Standards Agency has established a reliability testing program. This program has three objectives:

1. The quantitative measurement of reliability and its expression in percent per thousand hours.
2. The anticipation of reliability specifications and to acquaint the Canadian Industry with techniques of measurements.
3. The improvement of the products by the analysis of failure modes.

The program is initially restricted to those parts which are qualified under MIL specifications. The basic procedure consists of procuring pre-screened parts and subjecting them to a variety of voltage and temperature stresses. Tests may run as long as 10,000 hours and the program is set up so that a 90% confidence level is achieved. Equipment for this purpose is almost completely automatic.

Results are expressed on a standard data sheet and particular care is taken to define the conditions under which the failure rate is expressed. Actual test results are presented. The information is maintained by additional tests conducted in the manufacturer's plant under conditions which are compatible with the original information. Certain engineering problems relating to the program, its methods and its equipments are discussed. Tests are being conducted with long term humidity and combinations of environmental stress conditions. (Author)

REVIEW: This seems to be a reasonably frank summary of the Canadian program, stating what they are trying to do and indicating the problems which they face. While this is a management type paper and, as such, contains no design information, some details of the testing procedures are given.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Practical aspects of a high reliability specification

AUTHORS: Thomas W. Gross and John A. Sand, III, Lockheed Missiles and Space Company, Sunnyvale, California

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 196-203, January, 1962

PURPOSE: To describe the problems and their solutions which are involved in converting to high reliability specifications for components.

ABSTRACT: The PSMR-1 (Darnell Report) was sponsored by the government to upgrade procurement specifications and policies for military equipment. Lockheed Missiles and Space Company (LMSC) has adopted these recommendations and is in the process of incorporating them into its operations. This is a long-term program and in order to get started at once, the Command Programmer (a critical package in the Agena missile) was selected for immediate action. Its components were tested, with encouraging results, but the program was not comprehensive enough.

Thirteen high reliability specifications for high use parts have been prepared. The Department of Defense is encouraging and supporting this work. The first of these specifications to be submitted to vendors was on precision, fixed film resistors. The responses of vendors varied from enthusiastic to not interested. The vendors were evaluated for the capability of producing and proving the high reliability parts. Since time was short, it was also necessary that they have adequate existing data on reliability. Other very practical problems such as minimum lot size, minimum guaranteed orders and cost were discussed with the potential vendors, only one of whom would be selected due to low volume requirements. Once the vendor is chosen other problems of a very practical nature must be solved; these include increased cost of the electronic package, how to handle the costs of qualification, and less than minimum lots. Changeover means changing details on many drawings and smoothly integrating the new parts without interrupting production. Getting subcontractors to agree to use these parts and then working out the costs and responsibility problems was a large task. As high reliability parts become more common and as they are built into a project to begin with, the problems in their use will be fewer. Even though the parts cost more, savings are expected on ultimate vehicle costs.

REVIEW: The changing of specifications in the midst of production runs is enormously complex. This is an example of a good "management-type" paper as opposed to the general ones on "organizing for reliability." The problems and attempted solutions are clearly described and make interesting and informative reading.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability evaluation by application derating

AUTHORS: Kenneth W. Davidson and Edward E. Johnson, Texas Instruments Incorporated, Dallas, Texas

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 204-216, January, 1962

PURPOSE: To present some preliminary results obtained from a large scale reliability investigation conducted on a high speed medium power silicon transistor.

ABSTRACT: This paper presents results from a reliability program being conducted on 7000 transistors subjected to various conditions of operation and storage for sustained periods of time. Results of data obtained at eight different reading times during 5000 hours of life test are presented. Quantitative descriptions, in terms of response surfaces, of the functional relationships between failure rate and stress factors such as case temperature, input voltage and power dissipation are given. The theory and assumptions made in the design of the test program are discussed. The method of providing an effective feedback system to production and engineering on modes of failure, device design weaknesses, and parameter distributions as an aid toward reliability improvement is described.

The program included operating life tests, storage life tests, accelerated testing techniques, and a step stress study. As a result of the program, the 2N696-2N697 device type has been redesigned. The defects analysis effort verified the major cause of failure to be temperature. An empirical relationship between temperature stress and operating life will, when fully developed, provide a means of accelerated testing for reliability prediction. (Authors in part)

REVIEW: This is a worthwhile description of the experience of one company in setting up a reliability program using automated data methods. As such, it should be of interest to others concerned with setting up such a program. The paper is well illustrated with tables, charts, and photographs.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Acceleration factor determination on glass capacitors

AUTHOR: Lawrence D. Hines, Corning Glass Works, Bradford, Pennsylvania

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 217-221, January, 1962

PURPOSE: To describe experiments and results on the testing of glass capacitors to determine acceleration factors for voltage and temperature.

ABSTRACT: Over 29,000 glass capacitors were tested at several voltages and temperatures in a factorial experiment. The number of samples in each group was adjusted so that the average number of failures at each condition would be the same. All specimens were "burned-in" at 1000 vdc for 50 hours. Capacitance, dissipation factor, and leakage current were measured before the test and at each successive 1000 hours. Drift failure was defined as a capacitance drift of more than 5% from the initial value or a dissipation factor exceeding set limits. A catastrophic failure was defined as an open or a short. Failure rates, assuming the exponential distribution, were calculated from the usual formulas. The reporting was done at 60% confidence. The tests showed, however, that the distribution was decidedly not exponential. A good fit was obtained with a Weibull distribution with $\beta < 1$ (decreasing failure rate with time). The average failure rate (exponential) data were fitted to a mathematical model of the form $w\, P^x y^T t^z$ where w, x, y, z are adjustable parameters. P is the ratio of applied to rated voltage, T is the temperature (^{o}C) and t is time. The correlation coefficient was 0.966, indicating an extremely good fit. The average failure rates (Weibull) were fitted to a model of the form $w\, x^P y^T$ and a correlation coefficient of 0.959 was obtained, which also indicates an extremely good fit.

Since these data definitely support the contention of a decreasing failure rate and since means are readily available for the more complex calculations, there is little excuse for continuing to use misleading calculations based on the exponential distribution.

Curves are presented which show the calculated values of failure rate and from which the acceleration factors can be determined. These are extrapolated from the region of the data to usual operating conditions.

REVIEW: This series of tests seems to have been well planned and well executed. The analysis is based on some unstated assumptions which may or may not be satisfied, e.g., the analysis of variance requires normality and can be rather sensitive to departures from it. Failure rates at other than 60% confidence might have given different values of the calculated parameters in the models. It is usually worthwhile to

calculate the uncertainty involved in any extrapolation (assuming the model to be true) because so often it turns out to be quite large.

The author has presented enough of his work so that the results can be evaluated. This is very commendable, and the fact that it does enable the reader to be more critical of the methods than is the case when they are not described should not deter authors from presenting a fair amount of detail in their papers.

The arguments for abandoning the exponential distribution seem quite cogent, and are based on evidence from a considerable amount of data. The author's recommendation that provision should be made in reliability specifications for determining the form of the failure distribution deserves emphasis. Such a determination could, at least in some cases, lead to more realistic acceptance test conditions than may presently be in use; both the consumer and the producer should be interested in this.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The problem of human-initiated failures

AUTHOR: David Meister, Head, Human Reliability Requirements Group, General Dynamics/Astronautics, San Diego, California

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 234-239, January, 1962

PURPOSE: To provide a summary of the factors involved in human-initiated failures.

ABSTRACT: There is evidence to indicate that human error accounts for from 20% to 50% of all equipment failures. Sometimes human error merely slows up the job operation, thus effectively producing system unreliability. Reliability engineers, who tend to be primarily equipment oriented, tend to pay little attention to human errors unless they are distinct causes of malfunctions. In this paper the term "human error failures" refers to human error whether it causes equipment malfunction or not. Human error failures may be broken down into five types: (1) design error, (2) fabrication error, (3) operating error, (4) maintenance error, and (5) contributory error (resulting partially from mechanical-electrical-electronic factors). The consequences may be put into three classes: (1) those which prevent the operation by causing a shutdown, (2) those which delay the operation, and (3) those which reveal a potentially unreliable situation. The seriousness of the human error can be assessed in terms of the delay imposed by the failure. Some of the inadequacies which cause human error failures occur in equipment design, skill levels, motivation, procedure descriptions, tools and equipment, and job environment.

The patterns and processes of analysis for human errors are listed and discussed. A basic difficulty is the lack of good information. A list is given of the factors that should be used in reporting. The present failure reporting system is discussed and suggestions are made for improvement in it.

REVIEW: This is an extensive summary of the factors which are important in the whole problem of human-initiated failures. It is more a listing of these factors than an analysis. This is a subject which deserves the increasing attention it is receiving.

Other papers dealing with the human element in reliability have been covered by Abstracts and Reviews Serial Numbers 188 and 196.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A theory of component part life expectancies

AUTHORS: D. R. Earles and M. F. Eddins, The Avco Corporation Research and Advanced Development Division, Wilmington, Massachusetts, and D. R. Jackson, The Martin Company, Denver, Colorado

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 252-267, January, 1962

PURPOSE: To present the results of a study to estimate component part life expectancies with available data.

ABSTRACT: This paper is based on data collected over a period of a year and one-half, encompassing some 3000 data points, drawn from sources including satellites, laboratory computers, bench and life tests, ground operating equipment, shipboard equipment, aircraft, and missiles. Electronic, electrical, electromechanical, and dynamic mechanical equipment are represented. Although sample sizes are insufficient to permit the formulation of conclusive results, trends are evident and plausible reasoning processes can be used. Trend curves are used to synthesize life expectancies under various environments. To establish the life trend in relation to the installation environment, a plot is made of the component part life expectancy data for all types of components in scattergraph form. A mean is determined for life expectancies under each operating installation. The difference between the means of the different installation life expectancies permits the determination of K factors, which, when multiplied by the generic life expectancy, yield the predicted life expectancy for the remaining installation environments. The generic life expectancy is defined as the life expectancy under a laboratory computer installation and design philosophy.

It appears from the available data that the life expectancy is shortest for dynamic mechanical equipment, longest for electrical or electronic equipment, and has an intermediate value for electromechanical equipment. If life expectancy shortens as equipment becomes more dynamically mechanical in nature, then it follows that inelastic behavior is the most degrading mode of wearout, and drift the least. This leads to the suspicion that the first replacement of equipment is dependent on its susceptibility to change in composition with respect to time and environments. Electrical drift is less predictable and more in the category of a random type failure. Corrosion and thermoelectric wear are more predictable and, therefore, second in importance. The technique related in this paper permits some type of estimate to be made of life expectancy in the general case, but it is not recommended as a manner of selecting individual component parts for long life duty cycles due to the small sample sizes available to date.

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

The paper includes a brief discussion of the theoretical physics of failure under the headings Definition of Failure, Beltrami's Postulate, Definition of Failure Rate, Pierce's Postulate, Definition of Life Characteristic, and Dakin and Malmlow's Postulate. Empirical Failure Physics is discussed under the headings Burn-In Period, Normal Operating Period, and Wearout Period. Discussed under the heading of Life Expectancy are Life Expectancy Trend Analysis, Life Expectancy Modifiers, Generic Life Expectancies, and Average Environments. A listing of sources of data (Trade Journals and Industries) is given. An extensive table of Generic Life Expectancy Distributions (upper extreme, mean, and lower extreme) is included. Illustrative graphs are presented.

REVIEW: One often hears the remark from workers in the field of reliability that the scarcity of pertinent data on components and parts presents a serious limitation. A paper such as this is therefore very valuable. (See also an earlier paper by the first author, covered by Abstract and Review Serial Number 12.) The data and techniques will prove useful in studies of systems. The authors are careful to point out that better results will be made possible as more data become available; they imply that these studies will be continued. Such continuation should prove to be very worthwhile.

A point not covered in this paper, but of interest to users of components, is the question of widely different performance of components from different vendors. Some indication of the variability in this respect might prove useful.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability research on components for space

AUTHOR: Erich E. Brueschke, Aerospace Group, Hughes Aircraft Company, Culver City, California

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 281-295, January, 1962

PURPOSE: To summarize the effects of a simulated space environment on the reliability of electronic components.

ABSTRACT: The applications problems associated with the space environment are due to the high vacuum, electromagnetic and particulate radiation. Electronic components are generally not affected by micrometeorites and gravitational and magnetic fields. The materials of construction are more important in space than on an earth environment because of the different stresses.

High vacuum is the most far-reaching stress; it "causes" evaporation or sublimation of materials, loss of adsorbed and absorbed gases and elimination of convective heat transfer. Magnesium, cadmium, and zinc may cause trouble by sublimation and redeposition as conducting films on electronics circuitry or may impair optical systems. Aluminum, titanium and beryllium are quite safe. Inorganic coatings can be used to retard metal sublimation. Organic polymers and elastomeric materials generally do not evaporate, but their long chain molecules suffer degradation and breakdown into volatile short chain molecules. Plasticizers which cause difficulty even in the earth environment by evaporation are much more of a problem in the vacuum of space.

Protons are the most troublesome of the particle and electromagnetic radiations. They have considerable penetrating power and can generate other harmful radiation. Silicon and germanium have a reversible increase in leakage; if enough atoms are displaced, permanent effects will result. Organic compounds are affected by all radiation which forms foreign compounds. Digital circuits are affected more by transients than analog circuits are, but the susceptibility to large doses is reversed.

The space environment can be simulated mainly by high vacuums, radiation, and thermal extremes. Special high vacuum systems are described for the testing of components. The major effect on mechanical components which move is the removal of lubricating films and consequent galling. Some experiments are discussed. Resistors are affected mostly by high energy radiation with varying results. This radiation does affect some insulating materials, with the best capacitors being those which utilize inorganic insulation.

Derating of components is discussed and carbon composition resistors

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

are treated in some detail. There is no substitute for adequate testing of components in the space environment or in the simulated space environment prior to their application and this must be coupled with proper derating and protective schemes in the space vehicle.

REVIEW: As emphasized in the paper, this is a summary of the factors in the space environment which are important to the reliability of electronic components, rather than a listing of test results. It is a good paper on this important subject and contains 11 references. It does not have (or claim to have) material that design people need in selecting component parts for the space environment. It should, however, provide helpful insight regarding the effects to be anticipated. Other references on the effects of space environments on materials and components have been covered by Abstracts and Reviews Serial Numbers 81, 89, 107, 108, 145, 166, and 181.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: System maintainability

AUTHOR: Kenneth M. Hall, Sylvania Electric Products, Inc., Reconnaissance Systems Laboratory, Mountain View, California

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 310-321, January, 1962

PURPOSE: To determine the maintenance requirements (number of repairmen and spares) to keep a system in operation.

ABSTRACT: In placing a new system in the field, it is important to know the number of repairmen and spares required to make certain that the system will not be "down" longer than some specified period of time after a failure is detected.

Three models are derived in this paper. Model I determines the number of throw-away spares which are required at time 0 so that the probability will be 1 - γ that additional spares will not be needed in the time interval 0 to t. Model II determines the number of identical spare repairable units and the number of repairmen which are required at time 0 so that the probability will be 1 - ξ that the system will not be down due to lack of spares. For repairmen to service more than one type of unit, the general solution becomes quite complicated. By adding, however, the restriction that enough repairmen must be available at any instant in time to insure, with probability 1 - β, that when a failure is detected repair can be immediately initiated, a solution is obtained which is called Model III. The solution yields the minimum number of spares of each type which are required regardless of the number of repairmen available, and also the maximum number of repairmen needed regardless of the number of spares available. Examples, illustrating the models, and graphs are given in the paper. (Author in part)

REVIEW: This paper will be of interest to those who are concerned with the mathematical aspects of system maintainability. The models derived are interesting examples of the use of probability and queuing theory in the field of maintainability. The discussion of Model I should have included some statement about the magnitude of errors that could be expected when using the Poisson approximation.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design considerations for reliable electronic equipment

AUTHORS: W. J. West and H. S. Scheffler, Autonetics Division of North American Aviation, Downey, California

SOURCE: Proceedings Northeast Electronics Research and Engineering Meeting, Sessions 7 and 12, Reliability: A Design Criterion, sponsored by Boston Section, IRE-PGRQC, Boston, Massachusetts, pp. 2-1--2-18, November, 1961

PURPOSE: To discuss some of the techniques used at Autonetics for increasing the reliability of electronic systems.

ABSTRACT: The steps in the formulation and design of an electronic system are outlined as follows: (a) definition of the reliability requirements or objectives of the system, (b) determination of the mechanization for each type of equipment, and (c) apportionment of the reliability to subsystems, modules, components, and parts. These steps are discussed with reference to the Minuteman Reliability Program at Autonetics.

Several reliability design techniques are described. These include (a) use of the Standard Parts List and Handbook, (b) designing for tolerance to part-parameter drift, and (c) circuit design analysis. Under circuit design analysis the methods discussed are (1) modified and expanded (MANDEX) worst-case method, (2) parameter variation method, (3) VINIL (V_{IN} vs I_{LOAD}) method, (4) moment method, and (5) Monte Carlo method. Also considered are analysis of board layout for ability to withstand environmental effects, and design review. Illustrative diagrams, figures, graphs, and tables are included.

REVIEW: This is a very worthwhile description of some of the considerations, procedures, and analytical techniques that have been incorporated into the Minuteman Reliability Program. The descriptions are in general presented in sufficient detail to permit the engineer to get a good picture of the techniques. The accompanying illustrative material is also helpful. This paper is the full text of the Autonetics Report mentioned in Review Serial Number 192.

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R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

TITLE: Predicting the reliability of satellite systems

AUTHOR: R. H. Myers, Manager, Reliability Assurance, Aerospace Group, Hughes Aircraft Company, Culver City, California

SOURCE: Proceedings Northeast Electronics Research and Engineering Meeting, Sessions 7 and 12, Reliability: A Design Criterion, sponsored by Boston Section, IRE-PGRQC, Boston, Massachusetts, pp. 3-1--3-6, November, 1961

This is the full text of the paper covered by Abstract and Review Serial Number 193.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability and design of electronic systems and equipment

AUTHOR: Fred Moskowitz, Laboratory for Electronics, Inc.

SOURCE: Proceedings Northeast Electronics Research and Engineering Meeting, Sessions 7 and 12, Reliability: A Design Criterion, sponsored by Boston Section, IRE-PGRQC, Boston, Massachusetts, pp. 4-1--4-13, November, 1961

PURPOSE: To outline the major reliability techniques available to the electronic systems designer and to comment on their applicability and limitations.

ABSTRACT: Following an introductory discussion of some of the developments in reliability engineering, the author presents a brief outline of the essential features of reliability theory. This outline leads to the exponential failure law; the normal and Gamma distributions are also mentioned. Some attention is devoted to the analogy between equipment failure and human mortality. The computation of reliability for non-redundant systems is outlined. Certain techniques for designing reliability into non-redundant systems are discussed. The following steps for designing reliability into equipment are recommended.

(1) Make an initial reliability calculation to establish reliability level of components needed to satisfy requirements.
(2) Design simplest circuit required to meet performance specifications.
(3) Perform detailed component analysis review on the design to determine where reliability improvements are to be applied.
(4) Improve reliability by design control of component thermal and electrical environment.
(5) Improve reliability by redesign to relaxed tolerance limits.

The improvement of reliability by redundancy is discussed and illustrated. Some remarks are made about possible future trends in reliability.

REVIEW: This paper will serve a useful purpose as a tutorial work on the topics covered, for the newcomer to the field of reliability. For those interested in obtaining further information, eight pertinent references are cited in the bibliography.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design reliability creation through management directives

AUTHOR: John W. Griswold, The Boeing Company, Seattle, Washington

SOURCE: Proceedings Northeast Electronics Research and Engineering Meeting, Sessions 7 and 12, Reliability: A Design Criterion, sponsored by Boston Section, IRE-PGRQC, Boston, Massachusetts, pp. 5-1--5-9, November, 1961

The paper of the above title and by the same author, appearing in the NEREM Record and covered by Abstract and Review Serial Number 195, is a somewhat summarized version of this paper. The main points omitted in the summary are the details of discussion of specific management directives and the listing of subtitles of reliability directives.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The human as an element in system reliability

AUTHOR: Joseph Spiegel, The Mitre Corporation, Bedford, Massachusetts

SOURCE: Proceedings Northeast Electronics Research and Engineering Meeting, Sessions 7 and 12, Reliability: A Design Criterion, sponsored by Boston Section, IRE-PGRQC, Boston, Massachusetts, pp. 6-1--6-8, November, 1961

PURPOSE: To discuss certain principles of system design which are aimed at reducing degrading influences on the human operator.

ABSTRACT: There are certain principles of system design that deal with the minimizing of the human propensity to degrade under adverse conditions. These are best stated as follows:

1. Only essential information should be presented.
2. Essential information should be presented through the most appropriate sensory channels.
3. Essential information should be presented when and where it is needed.
4. Information should be presented with maximum clarity.
5. Visual displays should be arranged for optimum use.
6. Interpretations and decisions should be as automatic as possible.
7. The number of possible decisions to be taken at a given time should be minimized.
8. The number of control devices or control actions should be at the minimum that is consistent with the purpose of the system.
9. There should be only one action pathway to produce a given effect.
10. Control devices should be easily identifiable.
11. Control devices should be designed for optimum use consistent with purpose.
12. The direction of movement of controls should be compatible with the effects to be produced.
13. Control devices should be arranged for optimum use.
14. The system should be so designed that it can be operated adequately under all anticipated operating conditions.
15. Delay time should be at a minimum.
16. Designs should take into account body dimensions of personnel who will operate the system.
17. Design should conform with the major preferences of experienced operators where experimentally determined specifications are not available.
18. The system should lend itself to reasonably optimum safe operation.

(Author)

The discussion in the paper is arranged under the four main headings I: The Human Workspace, II: The Visual Display, III: The Control Interface, and IV: Human Communication.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: This paper tends to be complementary to the one of the same title and by the same author in the NEREM Record (see Abstract and Review Serial Number 196). Very few papers in the reliability literature deal directly with human failures, despite the important role which they play in system unreliability. A paper such as this serves a worthwhile purpose in attracting attention to causes for human failure. Some 21 pertinent references are cited.

Another paper on this topic has been covered by Abstract and Review Serial Number 240.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Maintainability and material support costs

AUTHOR: Robert I. Moeller, Space Guidance Center, Federal Systems Division, International Business Machines Corporation, Owego, New York

SOURCE: Proceedings Northeast Electronics Research and Engineering Meeting, Sessions 7 and 12, Reliability: A Design Criterion, sponsored by Boston Section, IRE-PGRQC, Boston, Massachusetts, pp. 7-1--7-5, November, 1961

The text of this paper is the same as that of IBM report No. 61-907-404, covered by Abstract and Review Serial Number 197.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Weapon system design and supportability--a function of failure prediction

AUTHOR: Colonel Vernon J. Taylor, USAF

SOURCE: Proceedings Northeast Electronics Research and Engineering Meeting, Sessions 7 and 12, Reliability: A Design Criterion, sponsored by Boston Section, IRE-PGRQC, Boston, Massachusetts, pp. 8-1--8-6, November, 1961

This paper is essentially the same as the one covered by Abstract and Review Serial Number 198.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Interpreting MIL Specs for system reliability--Part II

AUTHOR: Anthony J. Finocchi, Director of Reliability Engineering, ITT Federal Laboratories, Nutley, New Jersey

SOURCE: Electronic Products Magazine, vol. 4, March, 1962, pp. 45-47

PURPOSE: To indicate the extent to which certain contractual quality control and reliability specifications can increase program costs.

ABSTRACT: A specification which will be included in many future military contracts is MIL-Q-9858--Quality Control System Requirements. This specification lists the requirements for an acceptable quality control system in a research and development or manufacturing facility. It requires the contractor to submit a quality control manual and quality control organization acceptable to the contracting agency. An acceptable manual must present a well organized scheme covering incoming inspection, in-process inspection, and final inspection. Methods of inspection, sampling plans and inspection procedures, purchasing control, vendor control, drawing control, workmanship details, reporting forms, flow of materials, flow of information, and handling of rejected materials must be detailed. A conservative estimate of the cost of producing such a manual is approximately $10,000, which does not include the cost of maintaining the scheme and keeping the manual up to date. Taking all relevant factors into account, it is reasoned that if nominal quality control methods are not normally practiced, an additional eight to 15 per cent should be included in the total bid estimate when MIL-Q-9858 is a requirement.

There are approximately 40 specifications dealing with reliability, which term is not synonymous with quality control. Some of the functions of the two groups overlap, but only in minor details. As with quality control, each of the reliability specifications requires the contractor to have or to establish a reliability organization qualified to perform elaborate engineering and mathematical studies on the equipment under contract. The cost of this effort can add 12 to 20 per cent to the total engineering cost. This does not automatically include the cost of AGREE testing; an illustration is given. The degree of detail specified by given accept or reject conditions under stated environmental conditions is indicated.

REVIEW: This is the second paper in a series, the first one of which was covered by Abstract and Review Serial Number 218. It contains useful advice to contractors regarding the potential costs involved in quality control and reliability specifications.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Interpreting MIL Specs for system reliability--Part III

AUTHOR: Anthony J. Finocchi, Director of Reliability Engineering, ITT Federal Laboratories, Nutley, New Jersey

SOURCE: Electronic Products Magazine, vol. 4, April, 1962, pp. 34-37

PURPOSE: To discuss the requirements of the general specifications for control of the design and construction of ground-based, airborne, missile and ship-borne electronic equipment.

ABSTRACT: The four general specifications MIL-E-4158, 5400, 8189, and 16400 deal respectively with Ground Electronic Equipment, Airborne Electronic Equipment, Missile Electronic Equipment, and Shipboard Electronic Equipment. The requirements and restrictions which exist in each of these documents in great detail are very expensive. Failure to appreciate their cost and to provide necessary time and money almost always leads to a frantic search for short cuts, makeshifts, and gambles. The result is always a product with poor reliability. Reliability must be developed gradually as the result of experience, knowledge, analysis, feedback, and care.

The four general specifications are lengthy and detailed, with many references to hundreds of other specifications. Illustrations are given. The qualification of nonstandard parts is discussed. Illustrations of reliability requirements are cited. Component definitions dealing with standard parts are discussed.

REVIEW: This is the third paper in a series, the first two of which were covered by Abstracts and Reviews Serial Numbers 218 and 251. It contains further useful information and advice for contractors regarding specifications for electronic equipment.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: SAE Production Forum on Reliability

AUTHOR: (Reported by L. S. Franklin, Convair Astronautics
Panel Chairman: D. R. Archibald, Convair Astronautics)

SOURCE: Report of 1960 Aerospace Manufacturing Forum at 1960 SAE National Aeronautic Meeting, Los Angeles, California, October, 1960, Society of Automotive Engineers paper SP-333, pp. 17-29 (summarized in SAE Journal, vol. 69, March, 1961, p. 31, under the title "Reliability hinges on management disciplines")

PURPOSE: To report the consensus of a panel on reliability.

ABSTRACT: The article is a collection of short paragraphs under the following headings: the overall reliability job; reliability achievement techniques; planning for reliability in manufacture; programs, plans, and reviews; a human factor consideration in reliability; verification of product reliability; product verification; reliability skills and motivation; reliability organization, reliability programming and cost considerations; and a question/answer section.

REVIEW: The reporting of such a panel is a difficult job. The method chosen is a collection of short statements, each one complete in itself. The beginner should exercise extreme caution in taking any one of them "as gospel." For example: "The basic cause of unreliability was defined as being 'strength variance in manufactured products'... ...the underlying cause of failure is manufacturing variance" is an oversimplification of the problem. In another section, the ultimate reliability is expressed as a product of several "partial" ones, such as "the probability that product was built within design tolerances." The formula is apparently intended to be exact, but is in fact rather misleading. It is suggested that "one chance in a million as the maximum acceptable probability that a given mode of failure will occur" is common and that in a process with controlled variance one need only repeat three times an acceptance test which will limit the chance of defect to 1%. This is a flagrant misuse of the product rule.

The experienced reliability engineer might wish to read the paper because of its nominal importance. He can make his own judgments about the worth of each thought.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of electronic equipment

AUTHOR: (Technical Committee Report)

SOURCE: The Journal of the British Institution of Radio Engineers, vol. 23, pp. 287-295, April, 1962

PURPOSE: To present a selected list of references on the topic of electronic equipment reliability, prefaced by some observations on the philosophical and administrative approach to the subject.

ABSTRACT: Philosophical and administrative factors are of prime importance in both the design and utilization phases of a project; they require a specially attentive attitude by technical management which must remain conscious of the possibility that such factors can be obliterated by the volume of purely technological considerations. Those who design and produce equipment must be prepared to welcome and heed conclusions and recommendations bearing on reliability in an atmosphere quite devoid of favour or recrimination. In this connection there is an undoubted need for a more open and forthright approach, within the professional circle, to those essentially human failings which do themselves largely contribute to the pattern of unreliability. Too often are there factors of an economic, competitive or merely aesthetic nature which conspire to delay the issue and obscure the facts.

Only by making the maximum use of every available piece of information on the mode of failure, may we hope to increase our knowledge of engineering for reliability. Unless we are successful in this, we shall, on the one hand, fail to provide the trouble-free products to which this technological age is entitled, and, on the other hand, find ourselves unable to produce the more complex systems that will be demanded in the future. Unreliability of a product in use poses a pressing challenge. The apparent impossibility of an immediate and complete cure in some cases should enhance rather than lessen efforts to find partial remedies. It is better to achieve reliability by a series of small improvements at relatively short time intervals rather than by one improvement made only after a long, indeterminate period. (Authors)

REVIEW: The observations made in this paper are very worthwhile. They will be of interest mainly to those concerned with reliability management. An important feature of the paper is the inclusion of a selected list of references giving appropriate emphasis to the existing substantial and authoritative technological contributions on reliability. The references (numbering 192, with dates between 1956 and 1962) are classified under the headings: Bibliographies; General Surveys, Observations and Proposals; Components; Design and Evaluation Techniques; Theoretical Principles and Procedures; Systems Aspects; Analytical Methods; Construction and Maintenance Practices; Specifications, Standards and Guides; and Books and Proceedings Published in Book Form.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Semiconductors and space radiation

AUTHOR: Leonard B. Gardner, Radiation Effects Group, Computer Research Section, Litton Systems, Inc., Woodland Hills, California

SOURCE: solid/state/design, vol. 3, April, 1962, pp. 42-46

PURPOSE: To present a criterion governing the selection of semiconductors for application in a space radiation environment.

ABSTRACT: The mechanisms of radiation damage in semiconductors are summarized. The space radiation environment is defined. It is seen to consist of the radiations from the inner and outer Van Allen Belts and the galactic and solar cosmic rays. When the fluxes of the constituent particles comprising these different radiations are examined with regard to the damage they might produce in semiconductors, it is seen that the proton flux of the inner belt is the most significant. Some of the difficulties of ascertaining the severity of the space radiation are presented. These difficulties involve the facts that (a) the amount of damage imparted by any radiation is dependent not only upon the total flux but also upon the energy distribution of the flux, (b) the correlation between neutron damage and proton damage is not well established at present, and (c) present-day proton irradiation facilities do not duplicate space either in energy distribution or in intensity, and permit the irradiation of only small packages.

A criterion for the selection of semiconductors for application in a space radiation environment is presented. The criterion is based upon extrapolating various reports respecting proton irradiations of selected devices. This was accomplished by using the experience gained with neutron irradiations and knowledge of the mechanism of damage. No attempt is made to correlate the observed damage in a neutron environment with that of a proton environment. Included with the selection criterion is a table of several recently developed semiconductors, listed according to their resistance to space radiation. Although this table is based upon the extrapolation of semiconductor performance in several environments, it is believed to be a realistic appraisal of the devices tested.

REVIEW: This paper will be of interest and value to designers concerned with semiconductors for use in the space environment. While the paper is self-contained, some 12 pertinent references are cited. Other papers dealing with radiation effects on components and materials have been covered by Abstracts and Reviews Serial Numbers 81, 89, 107, 108, 145, and 160.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A second progress report on TV-receiver reliability

AUTHOR: E. H. Boden, Advanced Applications Engineer, Receiving Tube Operations, Sylvania Electric Products, Inc., Emporium, Pennsylvania

SOURCE: Sylvania engineering information service, vol. 9, January, 1962, 4 pp.

PURPOSE: To bring up to date the previously published reports of this work.

ABSTRACT: This work was reported at the Chicago Spring Conference on Broadcast and TV Receivers, June, 1961. (See Abstract and Review Serial Number 76.) The paper brings the work up to date by reporting the results for the year 1960-1961. Failures of tubes have fallen from 3.6% (for the test) to 2.9%. Several tables are given of the failures by circuit function and by cause. More tube types each year experience no failures at all during 1500 hours at 130 Volts AC. (117 Volts AC is normal.) The 2.9% test failures corresponds to about 2% per 1000 hours at the accelerated (high line voltage) conditions or an extrapolated 1/2% per 1000 hours at normal conditions. Recently there have been no differences in failures between comparable single and double section tubes nor between transformer and series-string sets.

REVIEW: Papers of this kind are especially worthwhile in emphasizing the non-military aspects of reliability. Much more work of this sort could be done. The failure rate data will be of interest to designers. See also Abstract and Review Serial Number 142 for British experience in this field.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An application of discriminatory analysis to reliability

AUTHOR: Robert P. Castro

SOURCE: 4 pp., Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, April 5, 1962

PURPOSE: To present the minimum-risk solution of the classification problem as a criterion for predicting the eventual success or failure of a component.

ABSTRACT: In a group of components let ρ be the proportion of the group which will fail within a specified time interval and $(1-\rho)$ be the proportion which will perform successfully during the same interval. Let L be the ratio of the losses incurred by classifying an inferior component as a superior one and a superior component as an inferior one. Denote the joint probability density functions of n observable parameters, $\underline{p}$, of an arbitrary component as $f_S(\underline{p})$ and $f_I(\underline{p})$ depending on the true character of the component, superior (S) or inferior (I). The classification rule which minimizes the expected loss (risk) due to misclassification is given by

$$L\rho f_I(\underline{p}) < (1-\rho) f_S(\underline{p}) \text{; assign } \underline{p} \text{ to the superior group.}$$

$$L\rho f_I(\underline{p}) \geq (1-\rho) f_S(\underline{p}) \text{; assign } \underline{p} \text{ to the inferior group.}$$

The author briefly outlines the general minimum-risk solution for the classification problem and then discusses in some detail the special case where $f(\underline{p})$ has a multivariate normal form. Within the latter framework, he shows that the minimum-risk rule reduces to the usual linear discriminant analysis when the inferior and superior populations have a common variance-covariance structure.

REVIEW: The author has presented a compact and accessible exposition of the minimum-risk decision procedure in this paper. He notes that the solution can be translated into a practical tool only by replacing ρ, $f_I(\underline{p})$, and $f_S(\underline{p})$ with sample estimates. The reader is advised to consult the excellent text by Rao (especially Section 8b.3) to familiarize himself with the difficult problems and uncertainty of results associated with the currently employed estimation techniques before attempting to use the solution.

There appears to be a misprint on page 3 where the constant C should be given as

$$[L\rho|\sigma_I^{ij}|^{1/2}]/[(1-\rho)|\sigma_S^{ij}|^{1/2}].$$

REFERENCE: Rao, C. R. (1952). Advanced Statistics in Biometric Research, John Wiley and Sons, Inc., New York, pp. 287-300.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On certain redundant systems which operate at discrete times

AUTHOR: George Weiss, U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland (present address: Institute for Fluid Dynamics and Applied Mathematics, College Park, Maryland)

SOURCE: Technometrics, vol. 4, pp. 69-74, February, 1962

PURPOSE: To discuss the effect of using redundant components on the operation of systems which perform a given task repetitively.

ABSTRACT: The system considered consists of N multiplexed, independently operating elements, each with constant failure probability q for a single cycle. Two cases are dealt with, viz. Case I: When a component fails, it remains inoperative until replaced, and Case II: A component failing on one cycle can function on the next, or any following cycle. In both cases system failure at cycle n is defined to be a situation when r components have failed at cycle n for the first time. The probability distribution of n is obtained, leading in generalization to the geometric distribution. The effects of replacements on the failure cycle distribution are analyzed.

An example of the type of system treated in this paper is an aircraft wing structure supported by struts, such that the failure of a certain percentage of the total number of struts is equivalent to a failure of the wing support system. Other examples are suggested by other structural designs.

The present study does not take into account variations in the failure probabilities due to time and environmental conditions. However, the results presented are suggestive of the relation of reliability to the number of redundant components, and in certain cases have direct physical application. If instead of treating discrete cyclic processes, one were to pass to a limit of continuous time, the reliability functions would pass in the limit to exponential functions. The paper includes an example of the use of the formulae derived. The example involves an "r out of N" switching network, which fails only if r elements out of the original N fail.

REVIEW: This is a mathematical paper which will be of more interest to the theoretician than to the design engineer. However, the example gives some indication of the applicability of the results. The author is careful to point out a respect in which the study might be considered incomplete, and indicates some possibilities for extension of the theory.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Parameter-free and nonparametric tolerance limits: the exponential case

AUTHORS: Leo A. Goodman and Albert Madansky, University of Chicago, The RAND Corporation

SOURCE: Technometrics, vol. 4, pp. 75-95, February, 1962

PURPOSE: To develop exact one-sided and two-sided parameter-free tolerance intervals based on the first r ordered observations from a sample of size n from an exponential distribution, and to study the properties of these intervals.

ABSTRACT: There is evidence that certain time-to-failure data obtained in life testing have an exponential distribution. Suppose that a piece of equipment need only operate for T hours and that the consumer imposes the requirement that the probability that the equipment fails before T hours must be k or less (i.e., the reliability of the equipment must be at least 1-k). Based on a sample of exponentially distributed times to failure of pieces of equipment, the consumer must decide, at the 100P% level of confidence, whether or not the reliability of the piece of equipment is at least 1-k. In such a situation, and in others as well, one would wish to determine a statistic $L(X) = L(X_1,\ldots,X_n)$ such that one has 100P% confidence that the probability is at most k that a future unit will fail in a time shorter than the value $L(x) = L(x_1,\ldots,x_n)$ based on a sample from this distribution. This problem is one involving the use of one-sided tolerance limits. Such limits are developed in this paper.

In addition, various criteria for goodness of tolerance intervals are examined, and certain optimum properties of these intervals are demonstrated. However, with respect to the criteria of small expected length or expected coverage, these intervals are not always better than nonparametric tolerance intervals. The asymptotic behavior of these intervals is studied. The effect of assuming an exponential distribution, when in fact the distribution is a mixture of two exponentials, is briefly discussed.

A simple formula is given for computing the one-sided tolerance limits. However, as the calculation of the two-sided tolerance limits for the exponential distribution cannot be stated so compactly, tables of the limits are provided for r = 1(1)15, 1-k = .5, .75, .9, .95, and P = .9, .95, and .99. Also tabulated are the minimum sample size required for X_1 to be the lower one-sided nonparametric tolerance limits, for k = .001, .01(.01).05(.05).5 and P = .75, .95, .99, .999, as well as expected length, probability of coverage for fixed expected length, and expected coverage comparisons between the

lower one-sided parameter-free and nonparametric intervals for these values of k and P.

REVIEW: In view of the importance of the exponential distribution to life testing and reliability, this paper is a contribution to the body of statistical techniques available for analyzing data from this distribution. It will be of interest to both mathematical and applied statisticians.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability assurance provisions in specifications

AUTHOR: Charles J. Brzezinski, Office of the Assistant Secretary of Defense (Installations and Logistics)

SOURCE: Industrial Quality Control, vol. 18, April, 1962, pp. 9-11

PURPOSE: To discuss a method for revising certain specification requirements which in their present form are incapable of distinguishing between the most reliable and the least reliable parts produced to the same specification.

ABSTRACT: Existing specification requirements are not designed to identify parts which exceed the minimum reliability levels or to indicate the level of reliability these parts may be expected to meet. This article describes a new approach to the method of specifying testing procedures whereby the purchaser of a part can select the level of reliability he desires and be assured that this level will be met by the parts he receives.

Engineers responsible for reviewing specifications inevitably must ask themselves the following two questions, among others:
(1) Which requirements in this specification affect reliability?
(2) How effectively does this specification satisfy new or anticipated reliability requirements?
For evaluating the effectiveness of existing specification provisions, the following procedure is suggested:
(1) Establish a basic group of tests, with each group representing a clear-cut, explicit function.
(2) Examine the purpose of each test and then classify that test into its appropriate functional group.
It will be found that the tests set forth in existing specifications fit into one of the following three groups: (1) Conformance Inspections, (2) Environmental Tests, and (3) Life Tests. Characteristics of tests in each group are stated, and criteria are given for determining the type of inspection procedure to be specified. It is important to assure that a minimum quality level is not established as the sole and inflexible standard. While a minimum level must be specified, provisions should be made for automatically adjusting this level to whatever higher level may be attained as product performance is improved. This may be accomplished by a multilevel reliability requirement consisting of a number of sampling plans with each plan representing a different level of reliability. For a product with known life characteristics, these levels can be established in terms of specific failure rates. For a product with unknown life characteristics, they can be established in terms of percent failures. It is proposed to assure lot-by-lot reliability by life testing a sample from each lot, using a modified form of sequential sampling in conjunction with a qualification requirement.

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

It is proposed to include a provision for life testing the product to failure or for a long enough period to obtain information about its life characteristics.

REVIEW: This paper will be of interest to those concerned with specifications involving reliability assurance provisions. More detail on the multi-level reliability requirement is found in the paper by the same author covered by Abstract and Review Serial Number 207.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Commercial and military reliability--A discussion of similarities and differences

AUTHOR: August B. Mundel, Sonotone Corporation, Elmsford, New York

SOURCE: Industrial Quality Control, vol. 18, April, 1962, pp. 19-22

PURPOSE: To show that commercial and military reliability frequently have the same goals.

ABSTRACT: Individual consumers and military and commercial organizations alike have an interest in the reliability of the equipment which they purchase. Most designs allow for a margin of safety since actual limits of failure cannot be determined without individual destructive tests. The difference between the apparent margin of safety and the actual margin of safety may be called "the margin of ignorance." The greater the margin of ignorance, the lower will be the product in the scale of technical achievement. Efforts to compress the margin of ignorance to achieve the dazzling performance of missiles, weapons, and satellites or to achieve markedly lower costs for equivalent performance in consumer goods have led to problems in reliability. Some instances are cited to show that military experience parallels that which is normally encountered in trying to achieve industrial reliability. The 1960 Review of Progress of the ARINC Research Corporation describes progress in reducing maintenance support requirements. A significant finding has been that 50 to 80 percent of all electrical equipment malfunctions are the result of relatively slow part deterioration. Thus the role of preventive maintenance is important in the search for methods of optimizing reliability at minimum cost. The implications for the servicing of commercial equipment are discussed. The topics considered include service by replacement, the effective use of parts, and parts specifications for reliability. It is concluded that commercial and military reliability goals are alike in the following three areas.

1. Improved reliability may be achieved by proper maintenance. Preventive, corrective, and total maintenance time and costs may be lowest for the longer mean time between failures.

2. The proper design of systems and use of components is essential to minimize deterioration, parts replacement, and breakdowns, and to economically achieve greater mean time between failures.

3. More systematic, more realistic, and more extensive life and failure test data is needed by designers. (Author in part)

REVIEW: This paper is a worthwhile presentation of some conclusions drawn from six reports which are cited as references in the paper. The fact that commercial and military reliability goals are basically similar should not be surprising, but it does seem to be worth pointing up. The reader may be interested in the fact that the papers covered by Abstracts and Reviews Serial Numbers 12 and 241 have presented collections of some of the data for which a need is expressed in this paper.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability: a benefit of automation

AUTHOR: Howard H. Arnold, Manufacturing Development Department, Western Electric Company, Winston-Salem, North Carolina

SOURCE: The Western Electric Engineer, vol. 6, January, 1962, pp. 4-10

PURPOSE: To describe the steps taken to gain control over the process variables in the manufacture of deposited-carbon resistors so as to make possible automatic control with resultant improvement in the quality and reliability of the product.

ABSTRACT: The deposited-carbon resistor line at the North Carolina Works of the Western Electric Company has demonstrated that automatic control of an entire manufacturing operation can provide a very significant improvement in the consistency of manufacture, thereby improving both the quality and the reliability of the product. To effect this, it was necessary to change the product so as to utilize methods and materials which would be more reliable and to make the manufacturing process compatible with automation. An intensive investigation of the entire production process was made to gain the strict control over process variables which is essential to the use of automatic control.

The paper includes discussions of the need for high-reliability resistors, the problems involved in their production, and the advantages of automatic control. Phases of the operation in which changes were made in setting up automatic control are carbon coating, terminating, capping, helixing, and encapsulating. Each of these phases is briefly discussed. (Author in part)

REVIEW: This is one of a set of three papers under the over-all title "A Computer-Controlled Production Line," appearing in the January 1962 number of The Western Electric Engineer. It deals directly with the reliability aspects of automated processing, while the other two papers deal with other matters related to the computer-controlled operation. An earlier paper describing this production line was covered by Abstract and Review Serial Number 19.

This paper provides a description of the experience of one company in setting up a production process for a high-reliability component. Others faced with problems similar to those which were solved in setting up this operation should find the paper helpful. The principles involved undoubtedly have wide applicability.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Noise-performance in tin oxide resistors

AUTHOR: J. G. Curtis, Corning Electronic Components, Corning Glass Works, Bradford, Pennsylvania

SOURCE: Electronics, vol. 34, November 10, 1961, pp. 101-103 (summarized in Machine Design, vol. 34, January 4, 1962, p. 12 under the title "Noise gives clue to resistor life.")

PURPOSE: To report a correlation between poor performance and excess noise in certain resistors.

ABSTRACT: Past searches for correlation between noise and performance in resistors have been rather fruitless. Experiments with Corning tin oxide resistors have shown that all sub-standard resistors are noisy, although not all noisy resistors are sub-standard. One test showed that noisiness was correlated with defects in the geometry of the films. Another test showed a striking relationship between noise and performance (life test and temperature coefficient). The majority of rejected pieces (too noisy) would still exhibit satisfactory performance. Corning is continuing the experiments.

REVIEW: A more complete paper is available from the author. This work has potential importance in reliability areas since any method of predicting life from production line measurements is very valuable. So far, the results are not too definitive in that many good resistors would be eliminated by the tests.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of semiconductors

AUTHOR: G. R. Latham

SOURCE: Radio and Electronic Components, vol. 3, pp. 231-233, March, 1962 (presented at the Ferranti Conversazione on New Development in Solid-State Components, London, England, February, 1962)

PURPOSE: To discuss some aspects of reliability in semiconductor devices.

ABSTRACT: Manufacturers of semiconductor devices are faced with a particularly difficult problem in assessing the reliability of their products. For example, in order to establish with 90% confidence that the failure rate does not exceed 0.5% per 1000 hours, it is necessary to life test some 3000 devices per 1000 hours, and get less than ten failures. A similarly large number is required in assessing the improvement or degradation due to a process change. Accelerated life testing has failed to provide a solution because (a) the accelerated conditions necessary to obtain a reasonable proportion of failures in the sample are in no way related to the normal condition, and (b) it is impossible to obtain a sensible correlation curve when the experimental points are so far along the curve from the points of interest. The only satisfactory method of improving life test information found by Ferranti Ltd. is not to accelerate the life test conditions but to apply more rigorous characteristic tests to the most sensitive parameters during life. This is accomplished by the use of life tests which are designed to give the most pessimistic picture possible, with results obtained under the conditions which are most sensitive to change.

Results of life tests carried out at full ratings are no indication of what a customer will experience in average applications, because some derating is usually employed. The most important factors affecting the reliability of semiconductors are junction temperature, reverse voltage, and adverse mechanical environments. To get some idea of actual reliability in the field, Ferranti Ltd. have tried to obtain, from large users, extensive life histories of applications, as well as the return of failed devices in an untampered condition. Some of the results are presented. Predictive testing techniques for the detection of potential early failures are outlined. Reference is made to the adverse effects on reliability of handling, both mechanical and electrical, and to the fact that high reliability is inevitably expensive.

REVIEW: This is a useful presentation of ideas based on the experience of a British manufacturer. The lack of success reported for accelerated life testing on semiconductors is in contrast to the success reported for the technique in the paper covered by Abstract and Review Serial Number 165. The interested reader will wish to assess the arguments presented in both papers in the light of his own judgment and experience.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Advances in combined environmental testing

AUTHORS: Sherwin Lewis, Member of Technical Staff, Space Technology Laboratories, Inc. and Captain James P. Cooper, Directorate of Propulsion Development, Ballistic System Division, Air Force Systems Command

SOURCE: Environmental Quarterly, vol. 8, March, 1962, pp. 24-27

PURPOSE: To report on new combined environmental test techniques developed by the Air Force for advanced ballistic missile fluid system components.

ABSTRACT: In the continuing search for methods to improve fluid component reliability prior to actual flight, the Air Force undertook to develop methods and equipment to test functionally operating components under a simultaneous combination of all major flight environments. The environments included programmed or steady-state altitude, temperature, humidity, vibration (random or sinusoidal), and acceleration in conjunction with temperature conditioned fluid flow.

Problems in setting up the techniques were encountered in the following areas:

(1) Centrifugal acceleration on the jig, specimen and moving shaker element mass causing an outward displacement during radial vibration.

(2) Coriolis acceleration on the jig, specimen, and shaker coil mass during radial vibration.

(3) Centrifugal acceleration on the jig, specimen, and moving shaker element resulting in a transverse displacement during vibration normal to the centrifugal force.

(4) Vibration effects on the centrifuge structure.

(5) Problems in the simultaneous transfer of gaseous and liquid test fluids, particularly at high pressures or cryogenic temperatures, on and off the centrifuge.

(6) Transfer of sensitive electrical instrumentation measurements off the centrifuge.

(7) Practical problems associated with combining and controlling combinations of vibration, temperature, humidity and altitude, and mounting those combinations on centrifuge equipment.

The solutions to these problems are briefly described and their advantages and penalties are noted. (Authors in part)

REVIEW: As the authors have indicated, the combined environmental equipment discussed in this paper represents a significant step forward in the ability to simulate the environments of missile and space flight, but much remains to be done in establishing the potential of the equipment and methods for future applications. In view of the complexity of modern missiles and space vehicles, and the relatively small number of test specimens available, the area of simulated environmental testing is clearly very important.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of components for communication satellites

AUTHOR: I. M. Ross, Bell Telephone Laboratories, Murray Hill, New Jersey

SOURCE: The Bell System Technical Journal, vol. 41, pp. 635-662, March, 1962

PURPOSE: To discuss the reliability of components such as transistors, diodes, and solar cells in relation to the design of a communication satellite with adequate reliability.

ABSTRACT: A communication satellite system, using components which are either available or achievable within the capability of existing technology, is feasible in principle. Whether or not it is economical and therefore practical, depends upon the life expectancy of the system, and specifically on the life of the satellite itself. It is assumed in the paper that a satellite life of at least five years is a reasonable target in the design of a practical communication system. An example involving a fairly simple system (1000 components and no redundancy, with failure times distributed exponentially) is used to show that average failure rates in the neighborhood of 10 per 10^9 component hours are required to give anything approaching economical life. It is also shown that all components which are numerous require an equally high order of reliability (a consequence of the assumption of no redundancy in the example). It is noted that the reliability of connections between components cannot be ignored.

The reliability of components in general is discussed under the headings: Wear-Out Failure, Manufacturing Freak Failure, and Random Failure. The reliability of specific components is discussed under the headings: Transistors and Diodes, Travelling-Wave Tubes, and Solar Cells. It is concluded on the basis of observations in the field and results of accelerated aging tests that the reliability of transistors and diodes is at least sufficient to meet the requirements for a communication satellite system. It further appears that travelling-wave tubes can be made that will survive launch and should not limit the life in orbit. Finally, even under the most pessimistic assumptions as to the nature of the Van Allen belt, solar cell power plants can be provided, at a weight penalty, to meet the required life. Adequately reliable communication satellites can therefore be made, provided they incorporate components of proven integrity which are used in a conservative design. Initially such satellites must be simple. As higher component reliability is demonstrated, and as improved vehicles permit the launching of greater payloads, the complexity of the satellites may increase.

REVIEW: This is a clear and carefully presented discussion, based on conventional assumptions, which are clearly stated. The author takes a realistic look at a problem of current interest, and presents his findings in detail. Eleven pertinent references are cited.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reducing human errors by redesign of systems components

AUTHOR: M. Freitag, Group Engineer, Reliability Engineering, Ryan Electronics/ Ryan Aeronautical Company, San Diego, California

SOURCE: Electro-Technology, vol. 69, April, 1962, pp. 116-118

PURPOSE: To appraise, from a human-factors point of view, available manual control and display components used on instrument panels and consoles built to military specifications.

ABSTRACT: Systems human-engineering is seriously hampered by a lack of human-engineered components which incorporate error-preventing, fail-safe, easy-maintenance, and easy-installation features. Human-factors engineers often find that system-design requirements cannot be fulfilled because the necessary display and control characteristics are not present in or may be violated by available industrial components. Design decisions and trade-offs are often made at the expense of human engineering.

One of the shortcomings of component design that has been a cause of system failure is the insufficient use of kinesthetic and auditory cues in the design of manual-control components used to initiate or stop an action or change an ongoing function. There is also a need for better composition and identification of functional areas, such as panels of control switches. Suitable color coding would be helpful. Multiposition control switches should have sufficient spatial separation between discrete positions. The use of two-position toggle switches is dictated by human-engineering principles, but this requirement is often waived in favor of other considerations. Available push-button switches are not proportioned or designed for nonslip operation. The situation with regard to pointer knobs is better, but could be improved; some examples are given. Reference is also made to shortcomings in labeling devices and display components.

REVIEW: The difficulties discussed in this paper can be contributing causes to human-initiated failures in the operation of missile and space vehicle systems. It would seem that the solutions lie in the incorporation of human-factors requirements into specifications, to a greater extent than seems to have been done so far.

Other papers dealing with the human element in reliability have been covered by Abstracts and Reviews Serial Numbers 188, 196, 240, and 248.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A critical evaluation of electrical control devices

AUTHOR: S. F. Newman, Senior Project Engineer, Manufacturing Development, General Motors Technical Center, Warren, Michigan

SOURCE: Electro-Technology, vol. 69, April, 1962, pp. 203-206

PURPOSE: To review the shortcomings of relays, limit switches, and solenoid valves with respect to operating life on mass-production equipment as revealed by laboratory tests to destruction.

ABSTRACT: Downtime on industrial equipment can be extremely costly; hence it is important to identify the causes of equipment failures. The opinion is expressed that causes of downtime resulting from electrical failures may be classified as follows:

Misapplication of devices by the equipment builder	60%
Defective devices due to poor quality control by the device manufacturer	10%
Maladjustment, accidental damage, and abuses by the user plant	25%
Failure of devices at the end of full life span (OK)	5%

The term misapplication is taken to include such actions as the use of inferior devices to save on cost, the use of unsuitable devices due to lack of knowledge of plant operating conditions, mounting in unsuitable locations, mounting in positions favoring accidental mechanical damage, use of devices requiring frequent adjustment, and use at currents and voltages in excess of values which will permit achievement of maximum mechanical operating life.

In order to obtain specific information pertaining to component performance, accelerated life tests on a number of similar control devices purchased from different manufacturers have been run for the past seven years by General Motors. The objectives of the tests were to determine causes of failure, typical design faults, and the maximum reasonable operating life which could be expected. The design of the tests, and later the results, were discussed with the manufacturers' representatives--on their own particular devices only. One objective of the program is to assist in the evolution of more reliable devices. Other objectives are to assist in setting up specifications for industrial equipment to insure that proper devices are used appropriately and to make available to plant operating people data on application limitations, proper methods of application, possible lapses in quality control, and undesirable design features. The operating policies of the test program are briefly described and general conclusions are summarized for performance tests on five classes of electrical control devices. The five classes are contacts and their ratings, relays, limit

switches, proximity switches, and solenoid valves.

REVIEW: This article is intended to set up a goal for component manufacturers to shoot at--the goal being 100 million faultless operations on industrial equipment. The ideas discussed may well have wider applicability than the author suggests. In particular, the idea of feedback from the user to the manufacturer could well be promoted more than at present as a means of evolving more reliable devices in many areas.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of components in satellites

AUTHOR: G. W. A. Dummer, Royal Radar Establishment, Great Malvern, Worcestershire, England

SOURCE: The Journal of the British Institution of Radio Engineers, vol. 22, pp. 457-463, December, 1961 (presented at Convention: "Radio Techniques and Space Research," Oxford, England, July, 1961)

PURPOSE: To summarize the knowledge about the reliability of components in space vehicles.

ABSTRACT: Environmental conditions are: Launching shocks, acceleration and vibration; temperature extremes; high rates of change of temperature; low pressure (vacuum); high ozone content (100 times that at sea level); solar radiation effects; weightlessness (zero gravity); cosmic and X-ray radiation; micro-meteorite dust erosion; dissociated gases (oxidation effects). A table of typical accelerations is shown (4g to 30g); these and vibrations are taken care of by conventional guided missile techniques. The normal temperature is disturbed mainly by aerodynamic heating during launch and the heating and cooling in orbit. Solid state circuits can keep the normal temperatures low and there are techniques for minimizing the disturbing factors. The ambient extremes are about -80°F to about 1000°F. Hermetic sealing at atmospheric pressure will eliminate most of the troubles due to vacuum. The solar radiation distribution is shown in a table. A large part is suitable for energizing photocells. Little is known about weightlessness and experiments are difficult to perform in the laboratory. The effects of cosmic radiation and solar flare radiation surges are the subject of speculation and controversy. Semiconductors and people are the most easily damaged by these radiations. Micrometeorites as small as 10^{-16} gm can cause erosion of polished surfaces--but this does not harm the components inside.

Hermetic sealing and/or potting are good techniques for reducing the undesirable effects of any environment and are applicable to space problems. High quality components, specially designed and proved to withstand the stresses are another means of improving reliability. A table lists some special components (four resistors, two capacitors, one relay). Microminiaturization seems likely to improve some aspects of the reliability picture, but it is expected to have all the difficulties of transistor circuits.

REVIEW: This summary has a somewhat different approach than others which have been written recently. It is a good one and reflects the British attitudes A minor criticism is the implication that only the infrared rays cause heating, whereas any wavelength that is absorbed either causes heating or adds energy in some other manner. The list of references (eight) is apparently not intended to be complete.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Connectors and galvanic corrosion

AUTHOR: Martin S. Frant, Research Associate, AMP, Inc., Harrisburg, Pennsylvania

SOURCE: Electronic Industries, vol. 20, December, 1961, pp. 112-116

PURPOSE: To show the results of an environment-simulating test for connector corrosion.

ABSTRACT: The reliability of an electrical connection in a corrosive environment is difficult to predict because of at least four factors. (1) Adequate surface cleaning must occur when the joint is made. (2) The joint must be tight enough so that the environment cannot reach the metal-metal interface. (3) The metals should be innately resistant to the environment. (4) The metals should be chosen so that destructive galvanic corrosion does not occur. This paper is concerned with the fourth aspect. A simulated test was developed and used to evaluate many metals combinations. The two metals were put close together, but not touching. The other ends were connected by a low resistance recording milliammeter. The parts were immersed in 1% salt spray at 35°C in a standard salt spray cabinet.

Charts of corrosion current vs. time are shown for some metals. A summary table shows the results--which include the following:

A. Completely satisfactory combinations.

Copper vs. nickel-or gold-plated copper
Tin plated copper vs. aluminum, nickel-plated copper or solder-dipped copper
Aluminum vs. tin-plated aluminum (no copper undercoat).

B. Satisfactory combinations, slight galvanic corrosion.

Copper vs. silver-or tin-plated copper, solder-dipped copper
Aluminum vs. tin-plated aluminum (stannate process)

C. Borderline, moderate galvanic corrosion.

Gold-plated copper vs. solder-dipped copper
Aluminum vs. solder-dipped aluminum

D. Unsatisfactory, severe galvanic corrosion.

Aluminum vs. brass; copper; nickel-or silver-or gold-plated copper
Tin-plated aluminum vs. copper or silver-or gold-plated copper.

It should be emphasized that these lists are to be used only as a guide and that other conditions of preparation or use would give somewhat different results.

REVIEW: The paper has a fairly extensive list of references for further information. The problem of corrosion vs. reliability is a very difficult one and this paper does provide some help to the practicing engineer.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Insulating against nuclear effects

AUTHORS: James C. Kyle and Leslie E. Baird, Physical Sciences Corporation, Pasadena, California

SOURCE: Electronic Industries, vol. 20, December, 1961, pp. 124-127

PURPOSE: To publish the advantages of certain silico-ceramic compounds for complex environments.

ABSTRACT: Silicon and ceramic compounds are suitable for (1) electrical connectors, headers; (2) magnet wire coating, and (3) potting and encapsulation. For example, bead insulators can insulate for 180v and high vacuum under the following conditions: 10,000 psi, 850°F for 10,000 hours within a nuclear reactor environment, and corrosive fluids.

Glass is conventionally used for high vacuum electrical seals, but it is quite unsatisfactory in the presence of nuclear radiation. Ceramics, such as alumina, are also used in high vacuum electrical seals. Nuclear radiation and high temperatures combine to degrade the interfacial bond and thus destroy the vacuum seal.

The new silico-ceramic seals are suited for use with high temperature metals such as Inconel, some stainless steels, and titanium. A vacuum integrity of 2×10^{-9} std. cc He/sec at 800°F is assured. Even in a radiation environment of 10^{20} NVT accumulated during 20,000 hours, the seal is not lost. A reliability figure of 99.995% at 95% confidence was achieved.

A typical test is described. Data are given on wire coating properties and on materials for potting and encapsulation. Hardness and glazing compounds are available.

REVIEW: This article is largely a description of the properties of certain proprietary ceramic compounds. The quantitative reliability figures may be concerned with product performance during a short test rather than with the probability of good parts surviving for a stated length of time (no specific information is given). It is questionable whether 95% confidence in a 99.995% quality is a high enough confidence to justify that high a quality figure. It is more reasonable to have the two numbers much closer together (to be very confident of poor quality or not very confident of extremely high quality have little engineering meaning, although they may well be statistically valid).

This paper may be of interest to designers who need the reported properties, although the discussinn of materials other than the proprietary products is quite limited.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Quality control versus reliability

AUTHOR: Hall Cary, Battelle Memorial Institute, Columbus, Ohio

SOURCE: 8 pp., presented at 1961 SAE National Automobile Week, Detroit, Michigan, March, 1961, Society of Automotive Engineers paper 326A (summarized in SAE Journal, vol. 69, June, 1961, pp. 65-67 under the title "A painless way for your company to start a reliability campaign")

PURPOSE: To indicate why a reliability group is needed and how it should fit into an organization.

ABSTRACT: A quality control group measures the product characteristics against the specifications. These specifications are the engineering department's attempt to translate the requirements of many groups into a practical product. Reliability is a subjective term and is defined in terms of an individual's confidence. A consumer decides on the basis of his exposure to the product, its advertising, and social acceptance whether or not it is reliable. Simply stated, a reliable product does what the customer expects it to do. A technical definition equates reliability to the probability of successful performance for the length of time and under the conditions expected.

The reliability engineering effort should be organized to work toward a goal. Reliability engineering is like government--it is a function, not a discipline. These engineers should observe, criticize, instruct, and influence, but not do the engineering work. The design and production engineers link quality control and reliability. They have not emphasized reliability because the feedback on good reliability is very slow. There should be a reliability group along with cost, performance and styling groups to help provide this feedback. Quality control has grown from inspection to process control. It tries to maintain the high quality of production. The reliability group is active throughout the design and testing phases to make sure that reliability standards are considered. The two groups complement each other--both are necessary.

REVIEW: This is an introductory management type paper directed toward the automotive industry. It may be mildly controversial in its discussion of quality control versus reliability. There are several concepts of reliability used throughout the paper and they are not all mutually compatible, but they do illustrate the many uses of the word today.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A method for critiquing designs and predicting reliability in advance of hardware availability

AUTHOR: René Bussière, Curtiss-Wright Corporation

SOURCE: 9 pp., presented at 1961 SAE National Aeronautic Meeting, New York, New York, Society of Automotive Engineers paper 343A (summarized in SAE Journal, vol. 69, July, 1961, pp. 74-76)

PURPOSE: To show how to predict mechanical reliability.

ABSTRACT: A part will fail when the stress exceeds the strength. Both of these quantities are distributed statistically. The strength is a rather easily determined function, but the stress depends on many factors. A computer programmed Monte-Carlo approach was used to find the stress function. In many cases the probability density distribution can be approximated by the normal (Gaussian) distribution, for which tables are readily available. This procedure was applied to a turbine blade and the poor failure rate of the parts was predicted. This showed that the failures were caused by known events and thus the part could be re-designed for longer life. An example is given of a shear coupling design which was checked by this method.

REVIEW: This paper describes a statistical process for design and analysis which was apparently successful in two examples. In setting up the theory, materials were assumed to behave in certain ways and the theory will have validity only insofar as materials behave in those ways. Two assumptions bear special scrutiny. The first is the assumption that the effects of repeated (cyclic) stresses can be represented by the laws of probability for independent events. There is a whole body of literature on fatigue (fatigue is not even mentioned in the paper) which discusses the probability of failure vs. stress and number of cycles. The reader is advised to consult a reference such as [1] below. It is most likely that the formula in the paper is not valid for any particular case. The second assumption is that use of a few tests on material strength can give the probability density function (pdf) to the necessary accuracy. The method in this paper is very sensitive to the tails of the distribution for failure probabilities less than, say, 10%. In the examples cited the reliability is so close to one that the values of the two functions in the tail areas become critical. Caution should therefore be exercised in interpreting the results of using sample means and variances as estimates of the corresponding population parameters. When the estimates are based on small samples, the associated confidence intervals may be quite large. (For example, to have 95% confidence that the true standard deviation lies within $\pm$ 10% of the sample standard deviation would require a sample number greater than 100.) While the estimates of reliability are unbiased if the two distributions are normal, they may not be very precise when the samples are small. Review Serial Number 131 discusses the use of

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mathematical models in such cases as this. The example of the shear coupling seems to use the theory more reasonably. The confidence required is only 97% and only one stress cycle is considered. The agreement in the turbine blade example might well be considered fortuitous.

REFERENCE: [1] Sines and Waisman, Metal Fatigue, McGraw-Hill, 1959

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Initiating a body reliability program

AUTHOR: William E. Sehn, Director of Reliability, Fisher Body Division, General Motors Corporation, Warren, Michigan

SOURCE: 4 pp., presented at SAE Detroit Section, October 3, 1960, Society of Automotive Engineers paper S261 (summarized in SAE Journal, vol. 69, January, 1961, pp. 60-63 under the title "At Fisher Body: Reliability Program upgrades car bodies")

PURPOSE: To describe a reliability program for automobile bodies.

ABSTRACT: Body reliability incorporates the creation of a dependable product with the realistic factors of quality,cost,and maintenance. Mathematics is difficult to apply to the program because of the many qualitative factors such as safety, comfort, appearance, durability, and utility. The reliability group tries to increase customer satisfaction and to reduce maintenance. Modern manufacturing requires improved control for higher dependability and a reliability group seems a natural part of this effort. This group should: (1) control and use existing reliability facilities; (2) prevent recurrence of repetitive errors; (3) resolve frequent customer complaints; (4) create new products or processes; (5) create and control new reliability measures; and (6) collect and evaluate data. The responsibilities of this group are to observe the attributes of new products before production, to analyze engineering and production decisions, to check on field service complaints, to evaluate the quality of components and products, to check product performance, to initiate reliability education measures and to establish the necessary lines of communication.

The staff must fit into the organization at several levels and yet not duplicate existing facilities. Three levels are described. Several examples are given of "plus factors" in body production today--those that tend to make the product more reliable.

REVIEW: This paper deals with product attributes more usually put in the realm of quality rather than reliability (where the two are distinguished). While a "classic" definition of reliability is alluded to, it is not stated explicitly. If the one involving the probability of operating a given time under given conditions is meant, it is easy to see why it is difficult to apply in this case. While customer satisfaction is vitally important in a consumer product, its existence does not mean that the product is as reliable as engineering and cost will allow; it just means that the customer, for many of a variety of reasons, is satisfied. Therefore, it might be better to leave the customer attitudes out of the concept of reliability, even though field performance must be included in it. This paper may be of interest to those in the electronic and electro-mechanical fields to show what is happening about reliability elsewhere.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Body component reliability

AUTHOR: A. J. Hofweber, Director of Reliability, Ternstedt Division, General Motors Corporation, Detroit, Michigan

SOURCE: 4 pp., presented at SAE Detroit Section, October 3, 1960, Society of Automotive Engineers paper S262 (summarized in SAE Journal, vol. 69, February, 1961, pp. 41-43 under the title "Mortality curves spot reliability problems")

PURPOSE: To show the Ternstedt Division's approach to reliability.

ABSTRACT: Statistical probability theory derives mainly from activities of biologists and insurance actuaries. The survival curve shows a prenatal rise, a high infant mortality, a low level section and a high old age rise. The emphasis here is on the infant mortality section--or the elimination of nuisance failures in the first few miles of driving. The reliability effort is tied into the organization at all appropriate levels.

The engineering department is the first place to attack the problem. A reliability review is conducted on a new design by a group of engineers with varied backgrounds. They consider specifications, critical areas, tolerance stack-up, feasibility of manufacture and test evaluation. There are many feedback loops concerned with reliability during the design, testing, and production activities as well as from the customer. New engineering supplements such as coordinating templates have been introduced; initial tooling is then more accurate. Automatic assembly can improve quality and reliability and reduce cost. (Two examples are given.) Incoming inspection on stainless steels has been made much more rapid and corrective action can be taken sooner.

REVIEW: This paper is quite specific about what is meant by reliability. It limits the term and then shows what is being done. Design reviews are an essential part of the program. The title on the summary is rather misleading--the mortality curve is used only to define the area of interest.

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Part I of the Index lists the topical codes, and shows which serial numbered abstracts pertain. Since the pages for the first volume were made up as the monthly increments were produced, it was not possible to anticipate what coding would emerge at the end of the first volume year. Hence, these codes did not appear on the individual abstracts. Part II of the Index, therefore, provides a listing of each serial number and the topical codes embraced in the abstract of that number.

We hope this supplementary information will be of use to you.

Sincerely yours,

Heyward E. Canney Jr.

HEYWARD E. CANNEY, JR.
Program Coordinator
Office of Reliability & Quality Assurance

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Pan American Union (6)

Library of Congress (25)

National Academy of Sciences
2101 Constitution Ave. NW (25)

National Aeronautics and Space Administration (25)

Documents Library (AFSS-LR)

Headquarters Library

National Bureau of Standards (25)

Navy Department Library
Main Navy, Stop 48 (25)

U S Air Force Systems Command
Andrews AFB (25)

U S House of Representatives Library (25)

U S Senate Library (25)

FLORIDA

Melbourne

Radiation Incorporated
Box 37

Sarasota

Electro-Mechanical Research, Inc.

ILLINOIS

Chicago

Chicago Public Library

University of Chicago Library (37)

Evanston

Northwestern University Library

Urbana

University of Illinois Library

IOWA

Cedar Rapids

Collins Radio Company
5225 C Avenue NE

Iowa City

University of Iowa Library

KENTUCKY

Lexington

University of Kentucky Library

LOUISIANA

New Orleans

National Aeronautics and Space Administration
Michoud Operations
Box 26078 (26)

Tulane University Library

MARYLAND

Annapolis

United States Naval Academy

Baltimore

Johns-Hopkins Library (18)

Martin Company (3)

Bethesda

Booz-Allen Applied Research, Inc.
4815 Rugby Ave. (14)

College Park

Litton Industries, Inc.
4900 Calvert Rd.

Greenbelt

National Aeronautics and Space Administration
Goddard Space Flight Center

Rockville

Int'l Business Machines Corporation
Federal Systems Division
326 E. Montgomery Ave.

Washington Technological Associates

MASSACHUSETTS

Bedford

Geophysics Corporation of America

Boston

Boston Public Library
Copley Square (17)

Cambridge

Arthur D. Little, Incorporated

Harvard University Library (38)

Mass. Inst. of Technology Library (39)

Lexington

Raytheon Company
Spring St. (73)

Waltham

Sylvania Corporation
Electronic Systems Division
100 First Avenue (54)

MICHIGAN

Ann Arbor

University of Michigan Library

Detroit

Bendix Corporation
Fisher Bldg. (2)

Chrysler Corporation
Missile Division
Box 2628 (31)

Detroit Public Library

MINNESOTA

Minneapolis

Minneapolis Public Library
300 Nicollet Ave. (1)

Minneapolis-Honeywell Regulator Co.
2747 Fourth Ave. S. (8)

University of Minnesota Library

MISSOURI

Columbia

University of Missouri Library

St. Louis

McDonnell Aircraft Corporation
Box 516 (66)

St. Louis (city) Public Library (3)

NEBRASKA

Lincoln

University of Nebraska Library

NEW JERSEY

Denville

Thiokol Chemical Corporation
Reaction Motors Division

Long Branch

Electronic Associates, Inc.

Nutley

Int'l Telephone & Telegraph Corporation
Missiles & Space Systems Division
Federal Laboratories
500 Washington Ave. (10)

Princeton

Princeton University Library

Radio Corporation of America
Astro Electronics Division

Whippany

American Telephone & Telegraph Company
Bell Laboratories

Wood-Ridge

Curtiss-Wright Corporation
304 Valley Blvd.

NEW YORK

Buffalo

Bell Aerospace Corporation
Box 1 (5)

Elmhurst

Kollsman Instrument Corporation
80-08 45th Ave. (73)

Farmingdale

Republic Aviation Corporation

Garden City

American Bosch Arma Corporation

Ithaca

Cornell University Library

Long Island

Grumman Aircraft Engineering Corporation
Bethpage

Sperry Rand Corporation
Sperry Gyroscope Co.
Great Neck

New York City

ACF Industries, Inc.
750 Third Ave. (17)

American Institute of Physics
335 East 45th St. (17)

American Machine & Foundry Co.
Government Products Group
261 Madison Avenue (16)

American Society of Mechanical Engineers
345 East 47th St. (17)

Avco Corporation
750 Third Avenue (17)

Columbia University Library (27)

Electronics & Missiles Facilities, Inc.
2 Lafayette St. (7)

Ford Foundation
477 Madison Avenue (22)

Institute of Radio Engineers
1 East 79th St. (21)

New York Public Library
5th Ave. at 42nd St. (18)

Rockefeller Foundation
111 West 50th St. (20)

Western Electric Company, Inc.
222 Broadway

West Point

United States Military Academy

NORTH CAROLINA

Chapel Hill

Institute of Mathematical Statistics
University of North Carolina

University of North Carolina Library

Durham

Duke University Library

Research Triangle Institute
Box 490

OHIO

Akron

Goodyear Aircraft Corporation
1210 Massillon Road (15)

Cincinnati

University of Cincinnati Library (21)

Cleveland

Cleveland Public Library
325 Superior Avenue (14)

National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road (35)

National Aeronautics and Space Administration
Space Nuclear Propulsion Office - Cleveland
21000 Brookpark Road (35)

Thompson Ramo Wooldridge, Inc.
23555 Euclid Avenue (17)

Columbus

Battelle Memorial Institute
505 King Avenue (1)

Ohio State University Library (10)

Sandusky

National Aeronautics and Space Administration
Plum Brook Facilities

PENNSYLVANIA

Philadelphia

American Society for Testing Materials
1916 Race St. (3)

Free Library of Philadelphia
Logan Square (3)

General Electric Company
Missile & Space Vehicle Dept.
3198 Chestnut St. (1)

Philco Corporation
Government & Industrial Group
4700 Wissahickon Ave. (44)

University of Pennsylvania Library (4)

Pittsburgh

American Optical Company

Westinghouse Electric Corp.
3 Gateway Center (30)

TEXAS

Austin

University of Texas Library

Dallas

Ling-Temco-Vought, Inc.
Chance Vought Astronautics Div.
Box 5907 (22)

Texas Instruments, Inc.
Box 5012 (22)

Houston

National Aeronautics and Space Administration
Manned Spacecraft Center (1)

VIRGINIA

Charlottesville

University of Virginia Library

Hampton

National Aeronautics and Space Administration
Langley Research Center
Langley Station

Wallops Island

National Aeronautics and Space Administration
Wallops Station

WASHINGTON

Seattle

Boeing Company
Aerospace Division
Box 3707 (24)

Seattle Public Library

University of Washington Library

WISCONSIN

Madison

University of Wisconsin Library (6)

Milwaukee

A. O. Smith Corporation
Box 584
3533 N. 27th St. (1)

American Society for Quality Control
161 West Wisconsin Ave. (3)

Milwaukee Public Library
814 W. Wisconsin Ave. (3)

EUROPE

(Numbers in parentheses are postal zones)

BELGIUM

Brussels

International Institute of Theoretical Sciences
221 Avenue de Tervueren (15)

International Scientific Radio Union (URSI)
77 Place Emile Danes

FRANCE

Chatillon-sous-Bagneux (Seine)

International Union of Theoretical and Applied Mechanics
29 Avenue de la Division Leclerc

Paris

ICSU Abstracting Board
292 rue Saint-Martin (3)

International Academy of Astronautics
12 rue de Gramont (2)

International Institution for Production Engineering Research
44 rue de Rennes (6)

Union of International Engineering Organizations
62 rue de Courcelles (8)

GERMANY

Hanover

International Association of Technical University Libraries
Bibliotek der technischen Hochschule
Am Welfengarten 1

NETHERLANDS

Hague

Committee on Space Research (COSPAR)
28 Nieuwe Schoolstraat

International Council of Scientific Unions (ICSU)
Paleis Noordeinde

International Statistical Institute
Oostduinlaan 2

SWITZERLAND

Zurich

International Mathematical Union
Eidgenösische technische Hochschule